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A shooting-star spectacular for the end of the year

#187 DECEMBER 2020

Sky at Night

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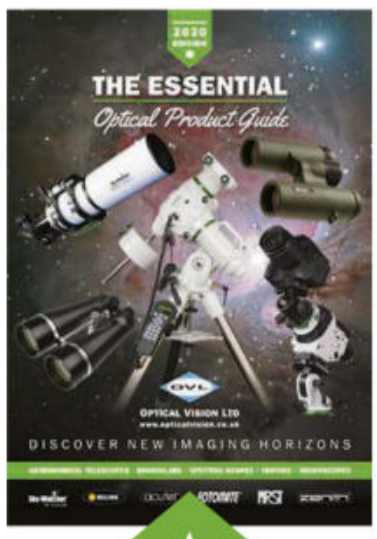

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Welcome

Get ready for the Great Conjunction of giant planets

As we look back on 2020 many will be reflecting on the historic nature of current events this year. There's one still to come, however, which will make astronomical history. On 21 December Jupiter and Saturn appear closer together than at any time in almost 400 years, and at first glance the Great Conjunction will look like a single bright star to the naked eye.

Although low to the horizon, it's undoubtedly worth seeking out this 'Christmas Star'. Discover its historic precedent with Neil Norman on **page 28**, and find observing notes with Pete Lawrence on **page 47**. For astrophotographers amongst us, keen to capture Jupiter and Saturn in a single frame, there's a detailed guide to imaging the spectacle on **page 76**; and Jane Green takes a look at the cultural impact of past Great Conjunctions in 'Field of View' on **page 25**.

The Great Conjunction comes hot on the heels of another event of note in the night sky this month – near-perfect conditions (astronomically speaking, we can't predict the weather!) for the Geminid meteor shower. With a strong peak of activity forecast for the middle of a dark night on 14 December, and no moonlight to spoil the show, this should be quite an event. Turn to **page 46** for our guide on how to observe these slow-burning, colourful meteors.

As you gaze skyward searching for shooting stars, spare a thought for the New Horizons spacecraft. This month it will be continuing its exploration through the far reaches of our cosmic neighbourhood when it images more of the icy bodies that orbit silently there, some 7.5 billion kilometres from the Sun. Will Gater takes up the story on **page 34**.

Enjoy the issue!

Chris Bramley, Editor

PS Our next issue goes on sale on Thursday 17 December.

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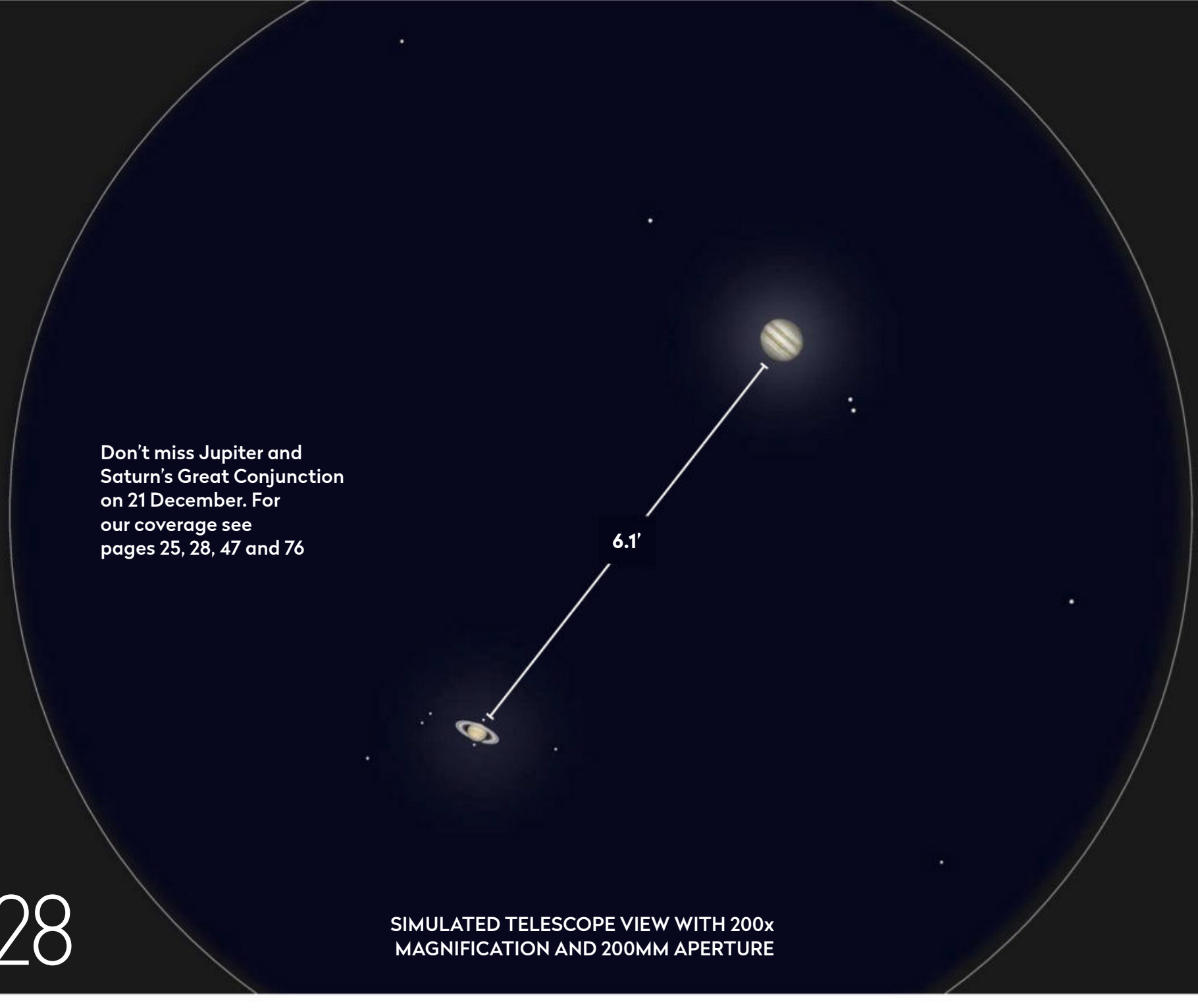

Don't miss Jupiter and Saturn's Great Conjunction on 21 December. For our coverage see pages 25, 28, 47 and 76

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New to astronomy?

To get started, check out our guides and glossary at
www.skyatnightmagazine.com/astronomy-for-beginners

This month's contributors

Jane Green

Astronomy writer

"Astronomy has inspired writers, poets and thinkers for centuries. It's been fascinating looking into Great Conjunctions in literature ahead of this month's spectacle."
Jane traces the literary mentions of Great Conjunctions, page 25

Neil Norman

Planetary observer

"I'm looking forward to the Great Conjunction on 21 December and came to realise its historic significance while writing my feature."
Neil compares Great Conjunctions over three centuries, page 28

Emily Winterburn

Physicist and historian

"I really enjoyed writing about Mary Somerville because she is such an inspiration. She was often told science wasn't for her, but she did it anyway."
Emily looks at the life of science writer Mary Somerville, page 40

Extra content ONLINE

Visit **www.skyatnightmagazine.com/bonus-content/UTVK4QE/** to access this month's selection of exclusive Bonus Content

DECEMBER HIGHLIGHTS

Interview: the biological Universe

We speak to biologist Wallace Arthur about why he believes life could be thriving throughout the Universe.

***The Sky at Night:* Beyond the Visible**

The team visit Jodrell Bank to find out more about astronomy that goes beyond what can be seen with the human eye.

Audiobook preview: Tim Peake's *Limitless*

Download and listen to two chapters from the British astronaut's brand new autobiography, narrated by Tim himself.

The Virtual Planetarium

Pete Lawrence and Paul Abel guide us through the best sights to see in the night sky this month.

GO WITH THE FLOW

Stars swirl like water down a plug hole as two galaxies start to merge

HUBBLE SPACE TELESCOPE, 23 OCTOBER 2020

Flying together at huge speeds, locked into a relationship that may eventually see them merge, these galaxies captured by the Hubble Space Telescope are NGC 2799 (left) and NGC 2798 (right), in the constellation of Lynx. Already the left galaxy is distorting under the other's influence, its stars appearing to peel away and fall into the centre of NGC 2798's spiral.

But don't hold your breath for a calamitous head-on collision – the process will last millions of years, perhaps even a billion. What's more, although galactic collisions may suggest chaos and destruction, the distances between each galaxy's components are so immense that they are more likely to pass through each other with little connection. Our own Milky Way is also on course for a similar collision, meeting our large spiralled neighbour, Andromeda in around 4 billion years, potentially merging into one mega-galaxy dubbed 'Milkomeda'.

MORE **ONLINE**

A gallery of these and more stunning space images

△ TAG, you're it

OSIRIS-REX, 20 OCTOBER 2020

It was only for six seconds that NASA's OSIRIS-REx touched down on Bennu – the ancient asteroid 321 million kilometres from Earth – but hopes are high that that was enough time to gather a sample of its surface materials. Mission planners, who'd struggled to find a suitable spot on the asteroid's boulder-strewn surface, were delighted with the Touch-And-Go (TAG) manoeuvre. "Literally, we crushed it," Dante Lauretta, the principal investigator said. "When the spacecraft made contact, that rock appears to fragment and shatter, which is great news."

◁ Fascinating frEGGS

HUBBLE SPACE TELESCOPE, 12 OCTOBER 2020

The purple edges in this image are where two stellar nurseries are meeting. This intriguing phenomenon is in J025157.5+600606, where newly minted massive stars are ionising the hydrogen of their birth clouds to produce bubbles of gas. Within these is a surprise: the newly discovered frEGGs (Free-floating Evaporating Gaseous Globules) – dark, dense clumps of cooler gas that themselves are birthing new low-mass stars.

◁ AI to the rescue

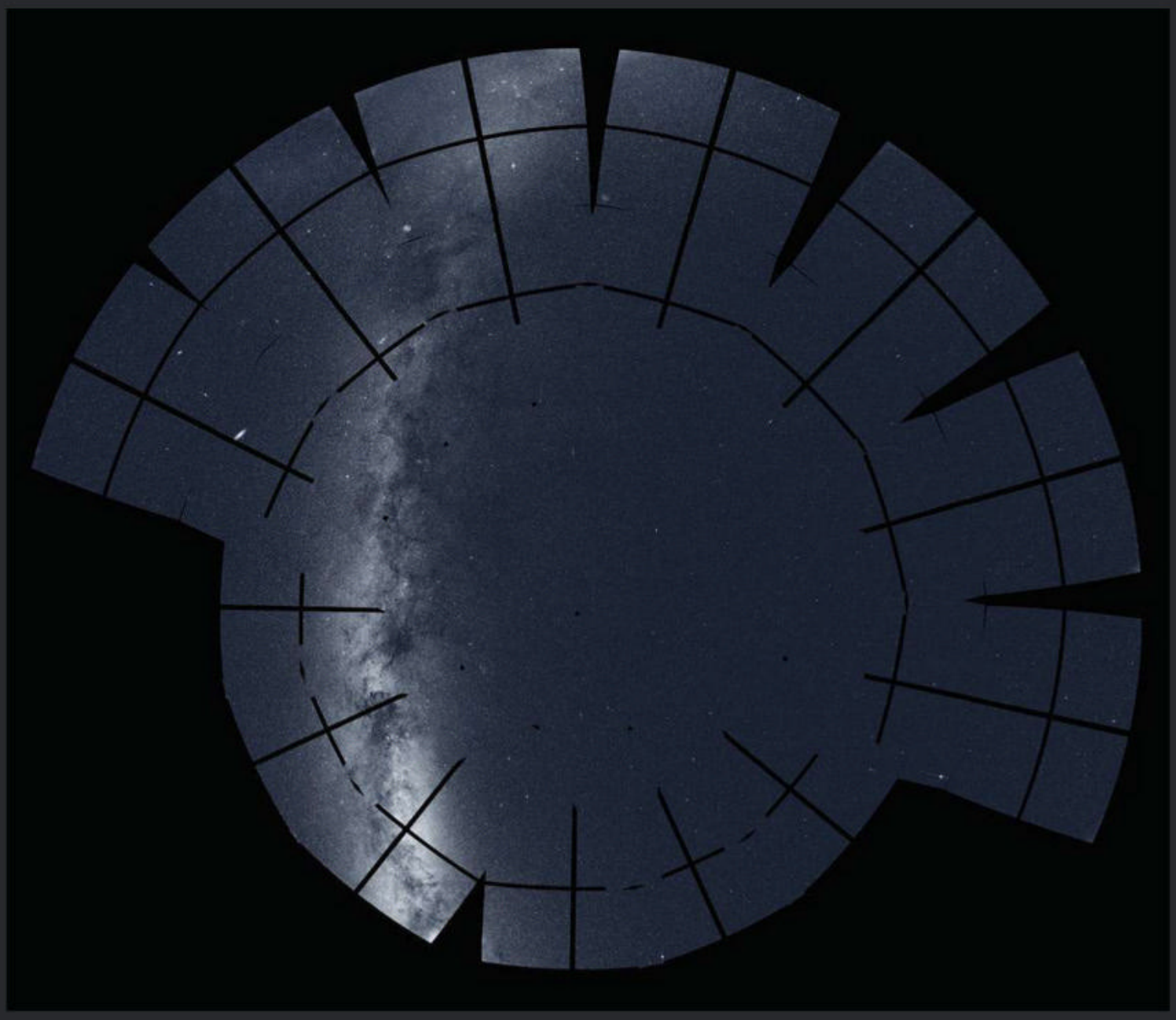
MARS RECONNAISSANCE ORBITER, 1 OCTOBER 2020

Spotting craters like these in the Noctis Fossae region, usually a painstaking manual task for researchers, is about to get easier: these are the first Martian features to be spotted by artificial intelligence (AI). A new machine-learning algorithm detected the craters, each no more than 4 metres wide, in images from the Mars Reconnaissance Orbiter's low-resolution Context Camera and it was confirmed by this image from the High-Resolution Imaging Science Experiment (HiRISE) camera.

▷ Northern sky panorama

TRANSITING EXOPLANET SURVEY SATELLITE (TESS), 5 OCTOBER 2020

As this 208-image mosaic of the northern sky shows, TESS's primary mission – to scan 75 per cent of the sky – is now complete. But with more than 40 terabytes of data to unpick, over 80 confirmed new worlds and more than 1,000 others still to sift through, this is just the beginning. Now turning its attention back to the southern sky as it enters its extended mission, there will be plenty to keep exoplanet researchers busy for many years to come.



◁ All aboard

INTERNATIONAL SPACE STATION, 18 OCTOBER 2020

Two spacecraft dock with the ISS as it glides above the Tasman Sea: Northrop Grumman's Cygnus resupply ship – with its golden cymbal-shaped solar array – delivering over 3,600kg of experiments, commercial products and other cargo; and Soyuz MS-17, depositing Expedition 64, NASA astronaut Kate Rubins and Russian cosmonauts Sergey Ryzhikov and Sergey Kud-Sverchkov. Up to eight spacecraft can dock with the ISS at once.

NASA/GODDARD/UNIVERSITY OF ARIZONA/LOCKHEED MARTIN, ESA/HUBBLE & NASA/R. SAHAI, NASA/MIT/TESS AND ETHAN KRUSE (USRA), NASA

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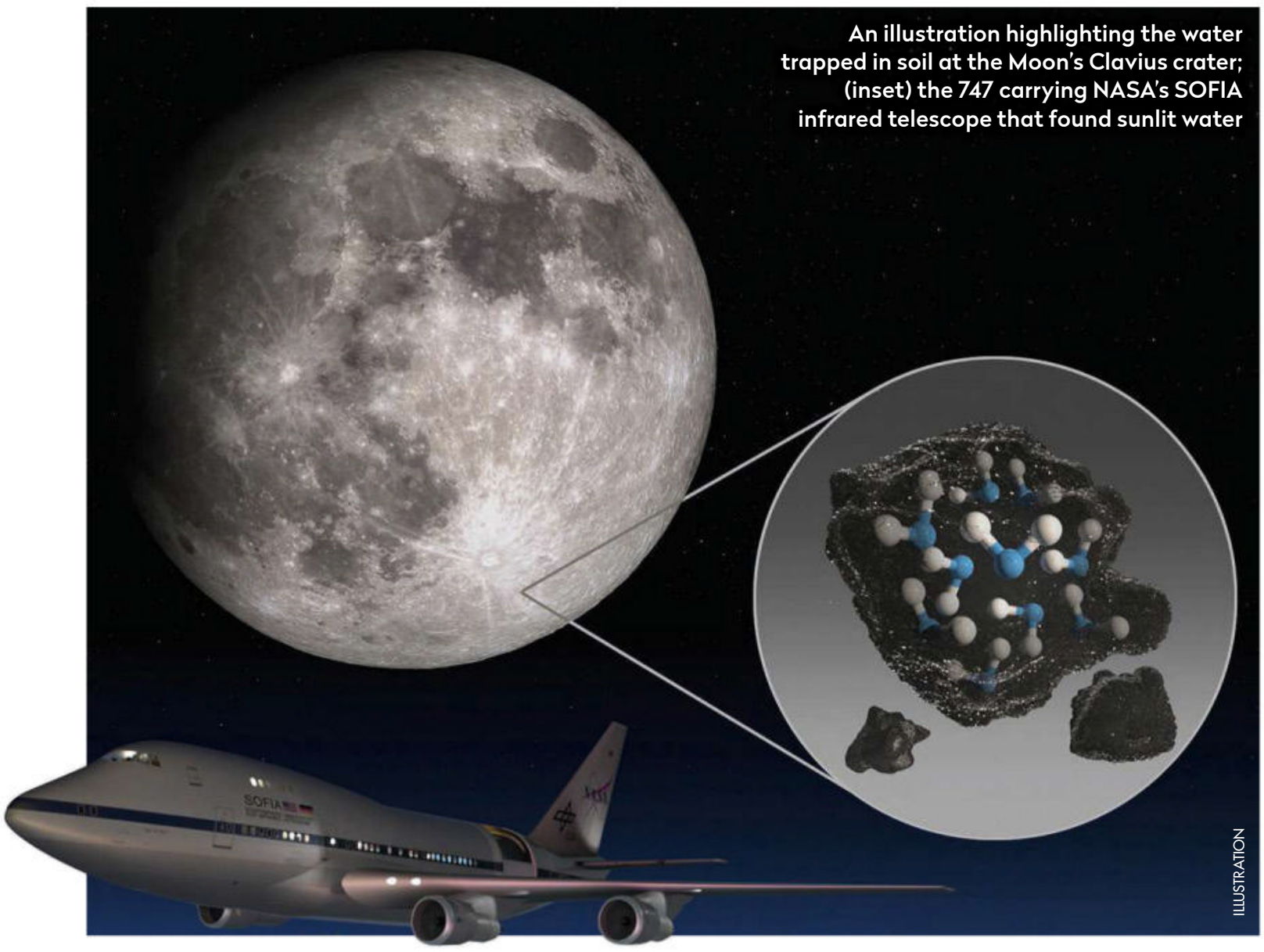


An illustration highlighting the water trapped in soil at the Moon's Clavius crater; (inset) the 747 carrying NASA's SOFIA infrared telescope that found sunlit water

NASA/DANIEL RUTTER

ILLUSTRATION

Water, water everywhere across the lunar surface

The Moon's water could be protected from sunlight inside glass beads

The Moon's sunlit surfaces could have water locked away within them, a recently released study has shown. Traces of ice are known to hide in the permanently shadowed craters of the southern pole, but this novel find suggests water could be spread across more of the surface – a hopeful sign for future missions hoping to investigate water on the lunar surface.

"Prior to the observations, we knew there was some kind of hydration," says Casey Honniball, who led the study while doing her graduate thesis at the University of Hawaii. "But we didn't know how much, if any, was actually water molecules like we drink every day, or something more like drain cleaner."

In an attempt to differentiate between the two, in August 2018 Honniball's team made a test observation of the lunar crater Clavius, using the aeroplane-borne infrared telescope SOFIA. Though intended as a trial, the readings were clear enough to reveal water – around one drink can's worth per cubic metre of surface soil.

"Without a thick atmosphere, water on the sunlit lunar surface should just be lost to space," says Honniball. "Yet somehow we're seeing it. Something is generating the water, and something must be trapping it there."

The leading theory is that micrometeorites carried water to the surface or created it on impact. The water was then trapped, a few molecules at a time, within tiny glass beads created by the heat of the collision.

Water on the Moon has also been touted as a potential resource for future lunar astronauts. However, exactly how to extract water frozen inside glass beads remains an open question.
https://sofia.usra.edu

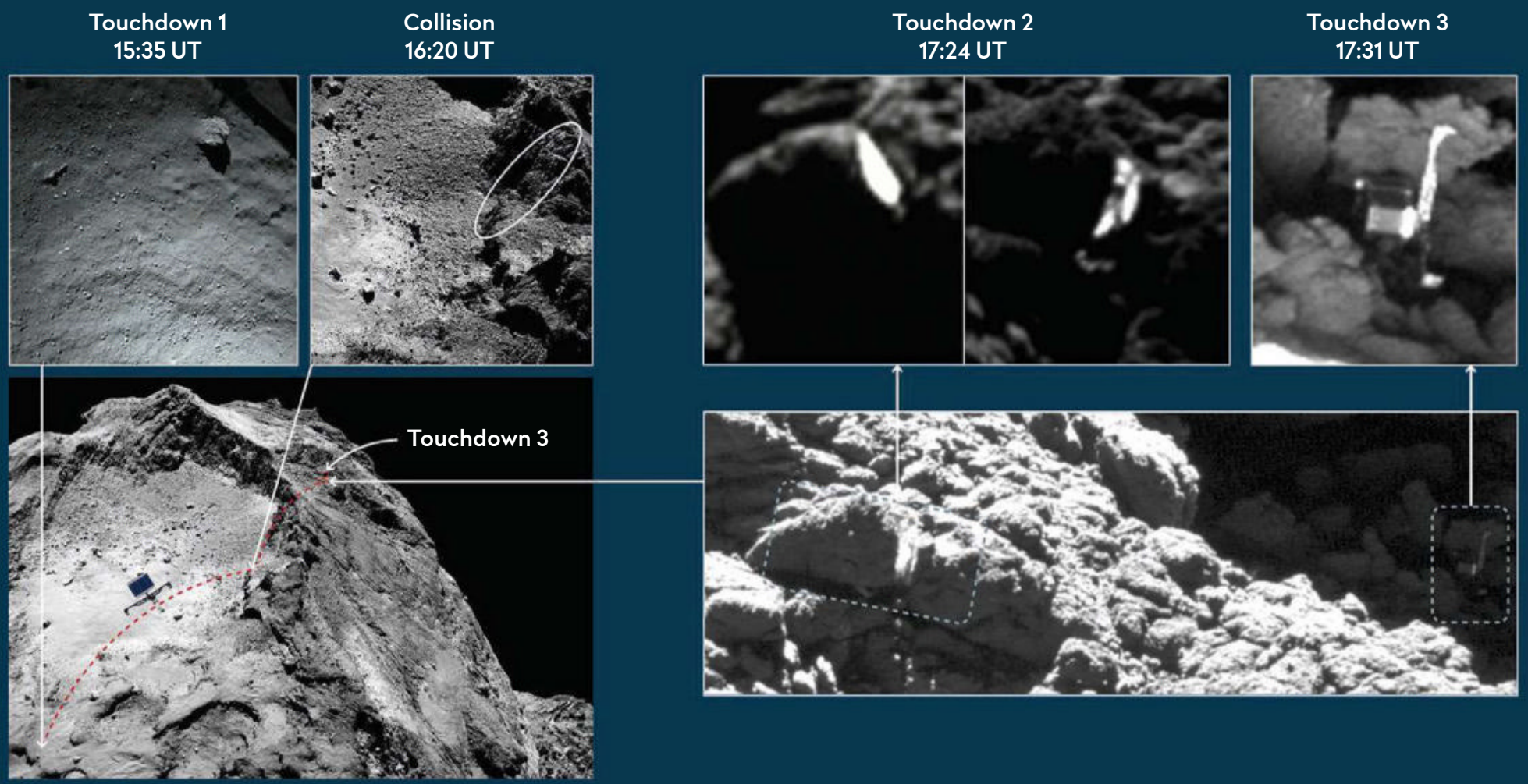
Comment

by Chris Lintott

Understanding the Moon's water might be a critical part of the understanding of our Solar System's history. Whether it's deposited by micrometeorites, the result of high energy particles in the solar wind striking the lunar soil, or got there another way, it's a valuable record. However, this latest discovery reveals that the lunar soil is, by any ordinary standard, bone dry. A cubic metre of lunar regolith weighs over a tonne; a drink can's worth of water is easily hidden in such bulk.

In theory we can imagine mining for water to fuel rockets, but any such scheme is far fetched; it's better to concentrate on the scientific yield from this resource, which is likely to be something worth digging for.

Chris Lintott co-presents *The Sky at Night*



▲ **Images reveal ESA's Philae touchdown sites on Comet 67P/Churyumov-Gerasimenko in context, with times in UT from 12 November 2014**

Philae's second comet landing site uncovered

The lander came down on a boulder with the consistence of cappuccino foam

The second landing site of ESA's Philae spacecraft has been found six years after the probe bounced across the surface of Comet 67P/Churyumov-Gerasimenko.

The lander descended to the surface of the comet after being released from orbiting spacecraft Rosetta, back on 12 November 2014, only to bounce off the surface twice before coming to rest. The sites of the first and final contact were found shortly after the landings, but the location of the second bounce remained elusive.

"Philae had left us with one final mystery waiting to be solved," says Laurence O'Rourke, the ESA scientist who led the search for the site of Philae's second landing. "It was important to find the touchdown site because sensors on Philae indicated that it had dug into the surface, most likely exposing the primitive ice hidden underneath, which would give us invaluable access to billions-of-years-old ice."

O'Rourke's team found the site with the help of an unexpected instrument – Philae's magnetometer, ROMAP. When the lander touched down, ROMAP's 48cm-boom arm bounced on the surface of the comet, creating spikes in its data. These revealed Philae was in contact with the surface for two minutes.

Using this to work out what shape of indentations they were looking for, the search party then hunted through images taken by the Rosetta orbiter's high-resolution OSIRIS camera. Eventually they found the brightly exposed ice of the landing site, and the impressions left by Philae between two adjacent boulders.

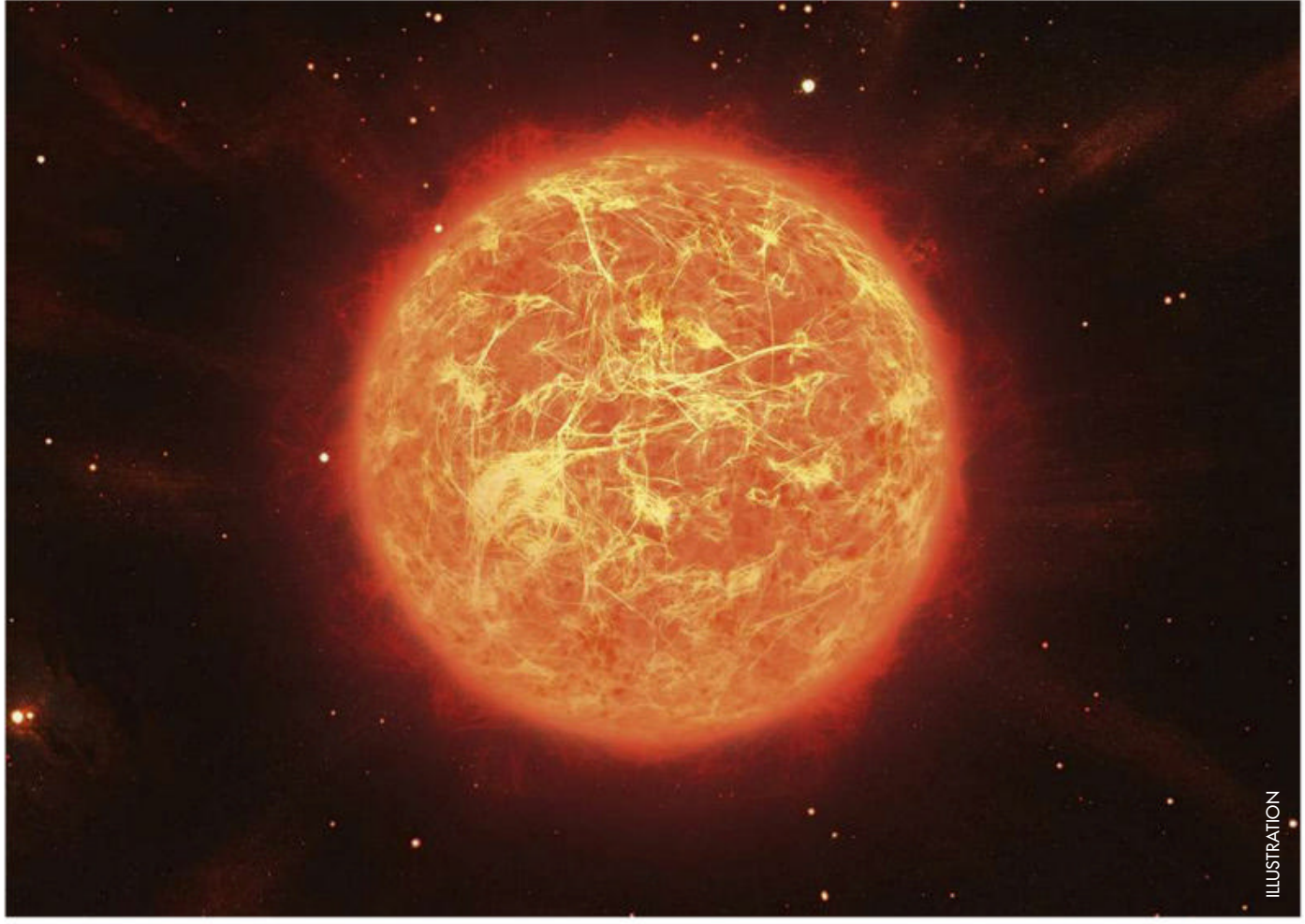
Knowing the type of terrain that Philae had come down in, O'Rourke then analysed the data taken by Philae during the bounce to make the first in situ measurement of the softness of the comet's icy-dust boulders.

"The simple action of Philae stamping into the side of the crevice allowed us to work out that this ancient, billions-of-years-old, icy-dust mixture is extraordinarily soft – fluffier than froth on a cappuccino, or the foam found in a bubble bath or on top of waves at the seashore," says Laurence.

This is in line with what had already been found for the bulk of the comet, but the confirmation will help future mission planners hoping to land on the surface of a comet.

www.esa.int

TOUCHDOWN 1: ESA/ROSETTA/PHILAE/ROLIS/DLR//ESA/ROSETTA/MPS FOR OSIRIS TEAM MPS/UPD/LAM/IAA/SSO/INTA/UPM/DASP/IDA/ANALYSIS: O'ROURKE ET AL (2020), PR3T3ND3R/ISTOCK.GETTY IMAGES, ESO/M. KORNMESSER, NASA/JPL-CALTECH



▲ Betelgeuse may have much longer to live than previously thought, with a lifespan of 100,000 years

Betelgeuse not so giant after all

The shrunken star is still 750 times wider than the Sun

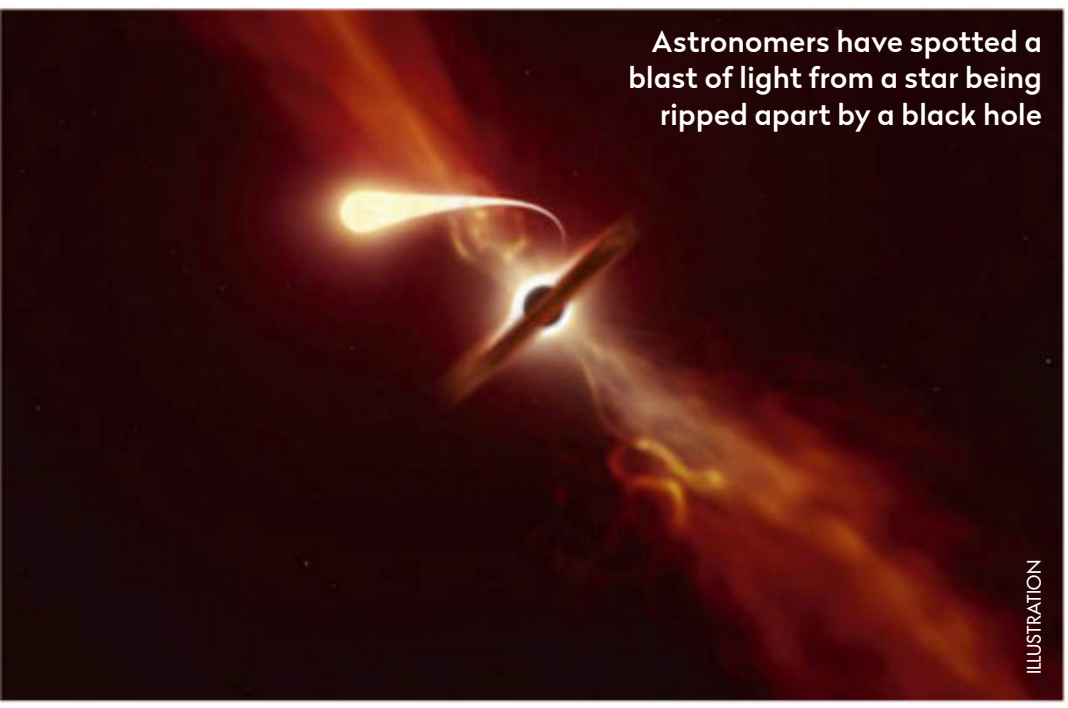
A new measurement of Betelgeuse suggests we might have misjudged the nearby red giant star: it's not only smaller than previously thought, it also has longer left to live.

Earlier this year, Betelgeuse went through an episode of unprecedented dimming. Using the wealth of telescopic data taken at the time, a group of astronomers were able to make a new measurement of Betelgeuse's size. This new diameter was a third smaller than previous measurements, suggesting the star's 'impending' supernova – which was expected to happen within 10,000 years – could be much further off.

"It's burning helium in its core at the moment, which means it's nowhere near exploding," says Meridith Joyce from the Australian National University, who led the study. "We could be looking at around 100,000 years before an explosion happens."

physics.anu.edu.au

Black hole snacks on spaghetti star



Astronomers have spotted a blast of light from a star being ripped apart by a black hole

Astronomers have captured a black hole devouring a 'spaghettified' star, in a newly released set of observations.

After spotting a flash of light near a supermassive black hole, astronomers turned their telescopes towards the system to witness the hole pulling a star into spaghetti-like streams of material.

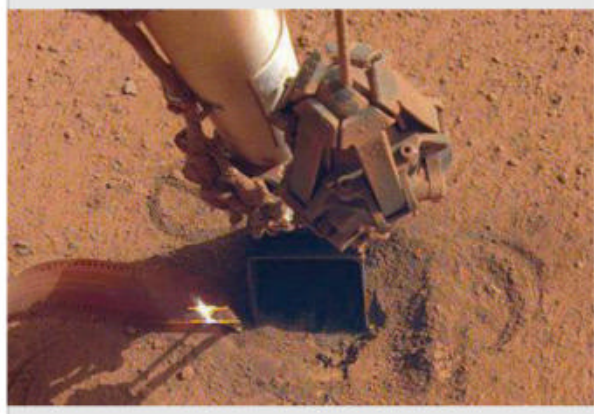
Normally such sights are difficult to catch. "When a black hole devours a star, it can launch a powerful blast of material outwards that obstructs our view," says Samantha Oates from the University of Birmingham, who took part in the study.

The team's rapid follow up meant they were able to catch the black hole just as it was beginning to blast material out at 10,000km/s.

"The observations showed that the star had roughly the same mass as our own Sun, and that it lost about half of that to the monster black hole, which is over a million times more massive," says Matt Nicholl, from the University of Birmingham, who led the study.

www.birmingham.ac.uk

NEWS IN BRIEF



InSight out of sight

After months of trying, NASA's InSight Mars lander finally got the head of its heat probe fully into the Martian surface – with a helping hand from the lander's robotic arm. The probe was meant to burrow itself into the soil, dragging a string of heat sensors behind it, but struggled to gain purchase in the loose soil.

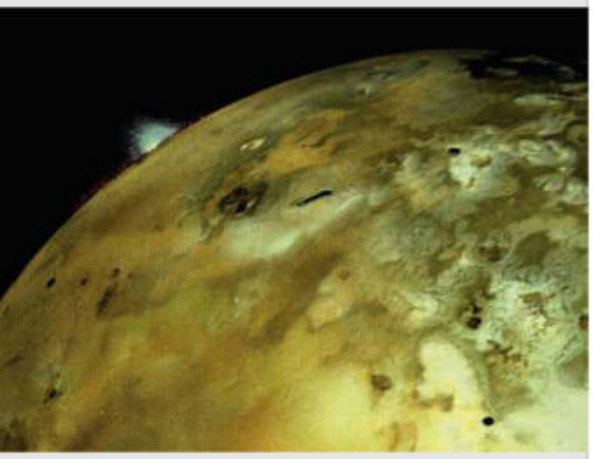
Earth's gold problem

Earth has too much gold. The element is normally created in the hearts of large stars, but there aren't enough nearby to explain Earth's rich veins of gold. A new study found even exotic gold creation methods involving neutron stars and black holes couldn't make up for the shortfall, begging the question: where does all this gold come from?

Baby star, baby planet

An infant planet has recently been spotted growing in a star system that's just 500,000 years old. The find suggests that stars and their planets grow up together like siblings, contrary to existing theories which assume only more mature stars can form planets.

NEWS IN BRIEF



NASA/JPL, ARMAGH OBSERVATORY, NASA/UNIVERSITY OF ARIZONA/TUCSON

Volcanoes feed Io's air

Around half the atmosphere of Jupiter's moon Io is belched out by its 400 volcanoes. Astronomers watched the moon pass through Jupiter's chilly shadow, causing the part of the atmosphere released by sunlight on the moon's surface to freeze, allowing them to measure the fraction created by volcanoes.

UK payloads to orbit

Two new competitions – one for students, another for start-up companies – are giving UK engineers the chance to get payloads put on a satellite and launched into orbit. For more details visit **http://orbastro.com**. The opportunity to sign up closes on 15 December 2020.

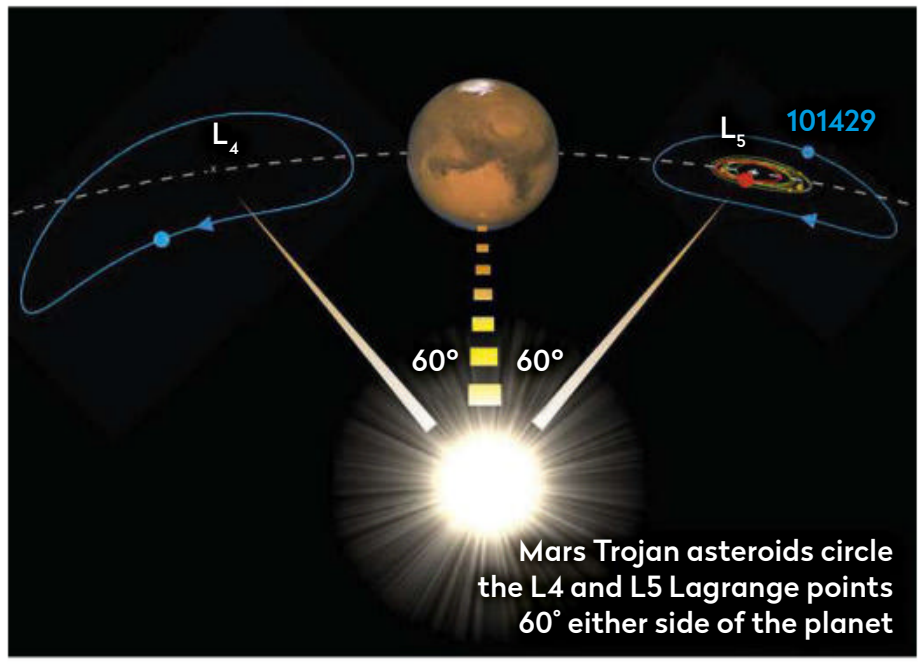
Guarding Earth-like planets

Earth-like planets form commonly with a Jupiter-sized companion, according to a recent set of computer simulations. Jupiter is thought to protect our planet from potentially dangerous objects, and the simulation showed giant planets could act as similar guardians, increasing their chances of evolving life.

BULLETIN

Moon-like asteroid hiding near Mars

It may have been flung across the Solar System by a lunar impact



Mars Trojan asteroids circle the L4 and L5 Lagrange points 60° either side of the planet

Has the Moon's long-lost twin been found near Mars? Recent observations of asteroid 101429 1998 VF31 – a Mars Trojan asteroid, meaning it shares the planet's orbit around the Sun – show the space rock has a Moon-like composition.

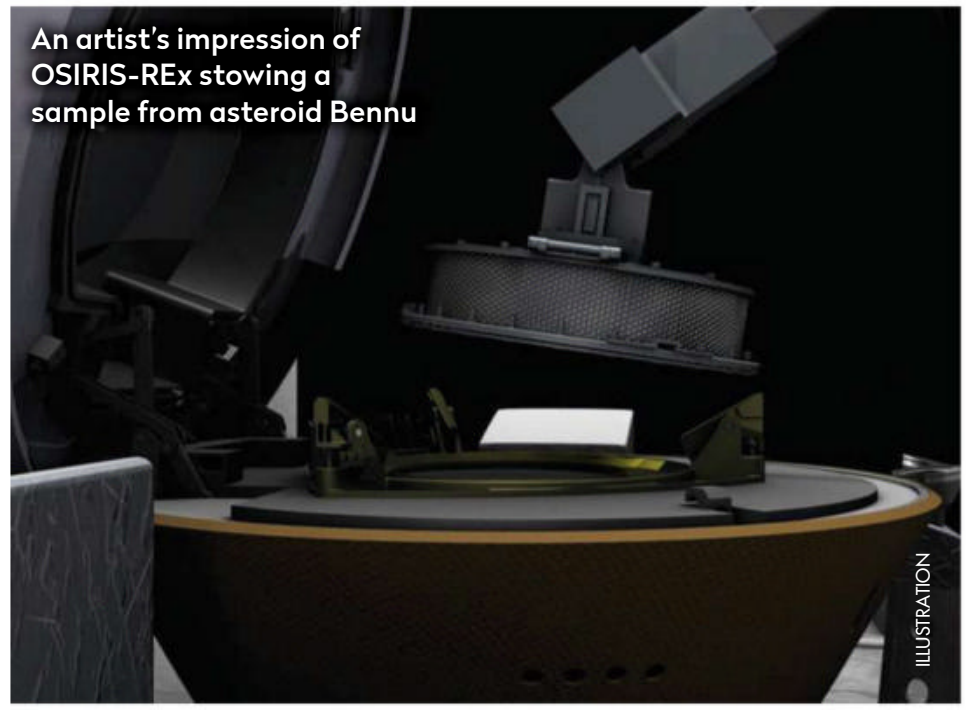
"The space between the newly formed planets was full of debris and collisions were commonplace," says Apostolos Christou from the Armagh Observatory and Planetarium in Northern Ireland, who led the study. "Large asteroids, we call these planetesimals, were hitting the Moon and the other planets."

One such collision could have knocked a fragment off the Moon and flung it towards Mars, where it was then trapped in the Trojan cloud.

Alternately, the asteroid could have been chipped off Mars. Christou's team will continue to investigate the formation of the asteroid and, perhaps, our own Moon as well.
https://armagh.space/

OSIRIS-REx forced to pack up early

NASA's asteroid investigating spacecraft, OSIRIS-REx, was so successful in harvesting rocks from the surface of asteroid Bennu, it managed to wedge itself open.



An artist's impression of OSIRIS-REx stowing a sample from asteroid Bennu

ILLUSTRATION

The spacecraft took its sample on 22 October by blasting nitrogen gas into the asteroid's surface, and then funnelling the dust kicked up into a container. However, several of the larger rocks it collected became stuck, meaning the mylar flap intended to seal the container couldn't close properly. This allowed the finer dust to seep out through the gaps.

To remedy the situation on 28 October, a week ahead of schedule, the team took the decision to securely stow the container that will return the sample to Earth. "The abundance of material we collected from Bennu made it possible to expediate our decision to stow," says Dante Lauretta, OSIRIS-REx's principal investigator from the University of Arizona. "Now we can look forward to receiving the sample here on Earth and opening up that capsule."
www.asteroidmission.org

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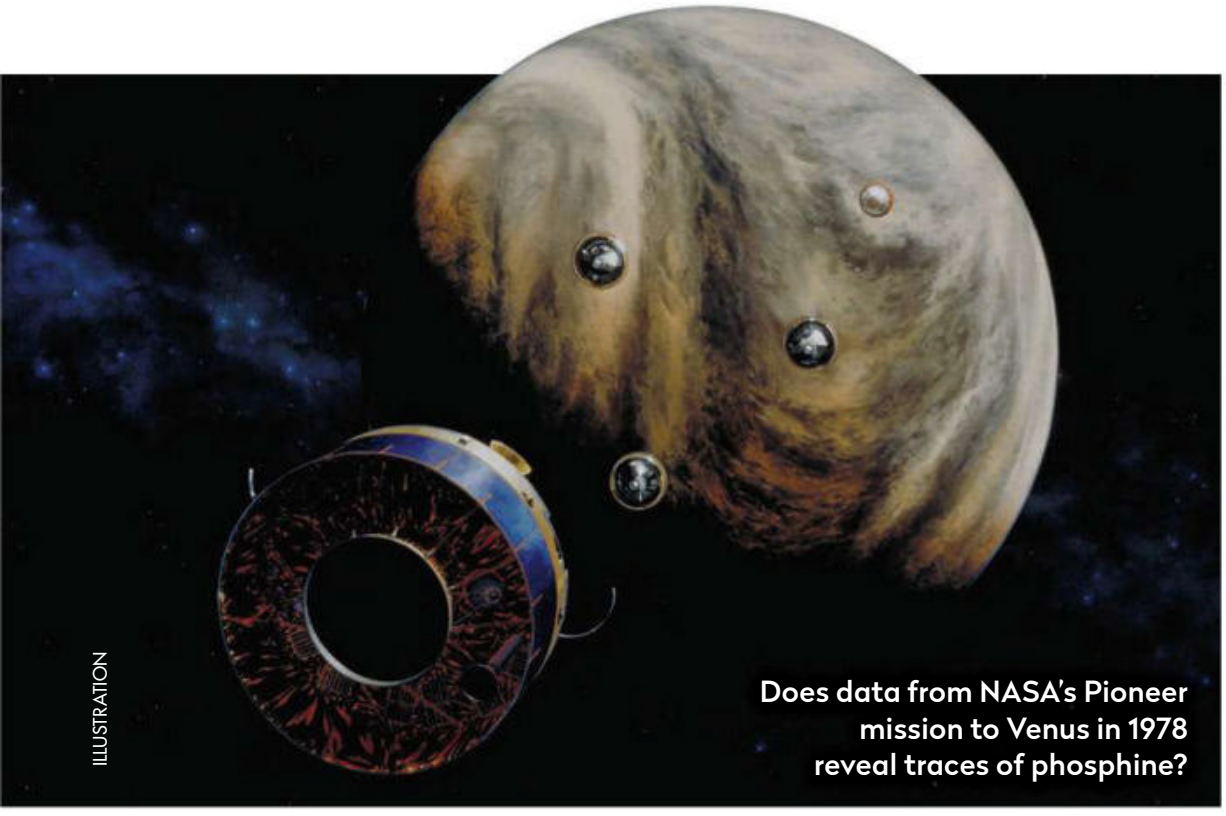
Our experts examine the hottest new research

CUTTING EDGE



ILLUSTRATION

Does data from NASA's Pioneer mission to Venus in 1978 reveal traces of phosphine?

Looking back into Venus's clouds

Scientists are checking for evidence of phosphine from Pioneer mission data

This September, a team of researchers led by Jane Greaves at Cardiff University published spectra collected by radio telescopes that indicated the presence of phosphine in the atmosphere of Venus. The debate this announcement subsequently triggered has been almost as heated as the Venusian climate... Experts have already published papers calling into question whether the gas is definitely there, as well as questioning what geological processes or atmospheric chemistry could have produced the gas, or whether it could feasibly be the signature of ultra-hardy Venusian life forms.

I was particularly taken by the response from Rakesh Mogul at Cal Poly Pomona, California, and his colleagues, who have gone back to reanalyse 40 year-old data. In December 1978 the Pioneer Venus multiprobe mission deployed four probes into the Venusian atmosphere. The largest of these had an onboard mass spectrometer that measured the concentrations of different gases as it parachuted towards the surface. Phosphorus compounds were not initially reported from these spectra, but Mogul has reanalysed this heritage data to see if there may have been signs of phosphine overlooked in the late 1970s.

Mogul stresses that they can only draw tentative conclusions from these mass spectra, but they are certainly tantalising. There is a signal at 33.992 amu (atomic mass units; phosphorus is ~30.9, and hydrogen ~1), which matches what you would expect from phosphine (PH3; 33.997). However, hydrogen sulphide (H2S) is also very close, at 33.987. Mogul and his team believe they can rule out a significant abundance of hydrogen sulphide though because there is no detection of isotope variants. If they're right, it means that phosphine may have been lying unnoticed in these Pioneer spectra for four decades.

Mogul and his colleagues submitted their analysis to the *Nature, Matters Arising* journal, which is set up to allow fast turn-around commentary or responses to recent publications. As such, this is one of the shortest papers I've reported on for 'Cutting Edge', just three pages without the bibliography, but I think it illustrates really well how scientific knowledge advances in jerky steps. One research group analyses their results as thoroughly and dutifully as they can and then submits their report to a journal. This data and their interpretation are then scrutinised by peer reviewers, before being published for the scientific community and a press release sent to journalists. Then, if it's particularly significant or controversial, other scientists around the world will race to attempt to replicate or refute the findings using alternative instruments or datasets. And this is what we are seeing playing out with the Venus phosphine announcement.

"The conclusions are tantalising... If they're right, it means that phosphine may have been lying unnoticed for four decades"

Mogul and his colleagues have poured back over heritage data from the early Pioneer probes; and without a doubt, astronomers will be scrambling to get observation time on ALMA or other radio telescopes to attempt to confirm the phosphine detection. There has also been a surge in interest to return to Venus with descent probes to investigate the cloud chemistry close-up. The DAVINCI probe, currently shortlisted for construction by NASA, is one particularly exciting prospect, but we'll have to wait until summer 2021 to see if it's selected.

Prof Lewis Dartnell is an astrobiologist at the University of Westminster

Lewis Dartnell was reading... *Is Phosphine in the Mass Spectra from Venus' Clouds?* by Rakesh Mogul et al. **Read it online at: https://arxiv.org/abs/2009.12758**

NASA/PAUL HUDSON, N.R.FULLER/NATIONAL SCIENCE FOUNDATION

Big stars influence early galaxies

The first stars controlled how galaxies grew for generations after their explosive deaths

Prof Chris Lintott is an astrophysicist and co-presenter on *The Sky at Night*

The first stars may well have been the most important objects in our 13.8 billion-year cosmic story; their light illuminated the end of the Universe's dark ages, which followed the Big Bang. Their deaths may have provided raw material, in the form of heavy elements forged in their cores, for each subsequent generation of stars.

Finding out what these stellar pioneers were really like is an important goal of modern astronomy, and it's hoped that the James Webb Space Telescope (JWST) – now, hopefully and finally, less than a year from launch – might catch a glimpse of their ancient light. A lot depends on how massive (and therefore how bright) these first stars really are, as well as how common they are – each galaxy may only get one of these stars.

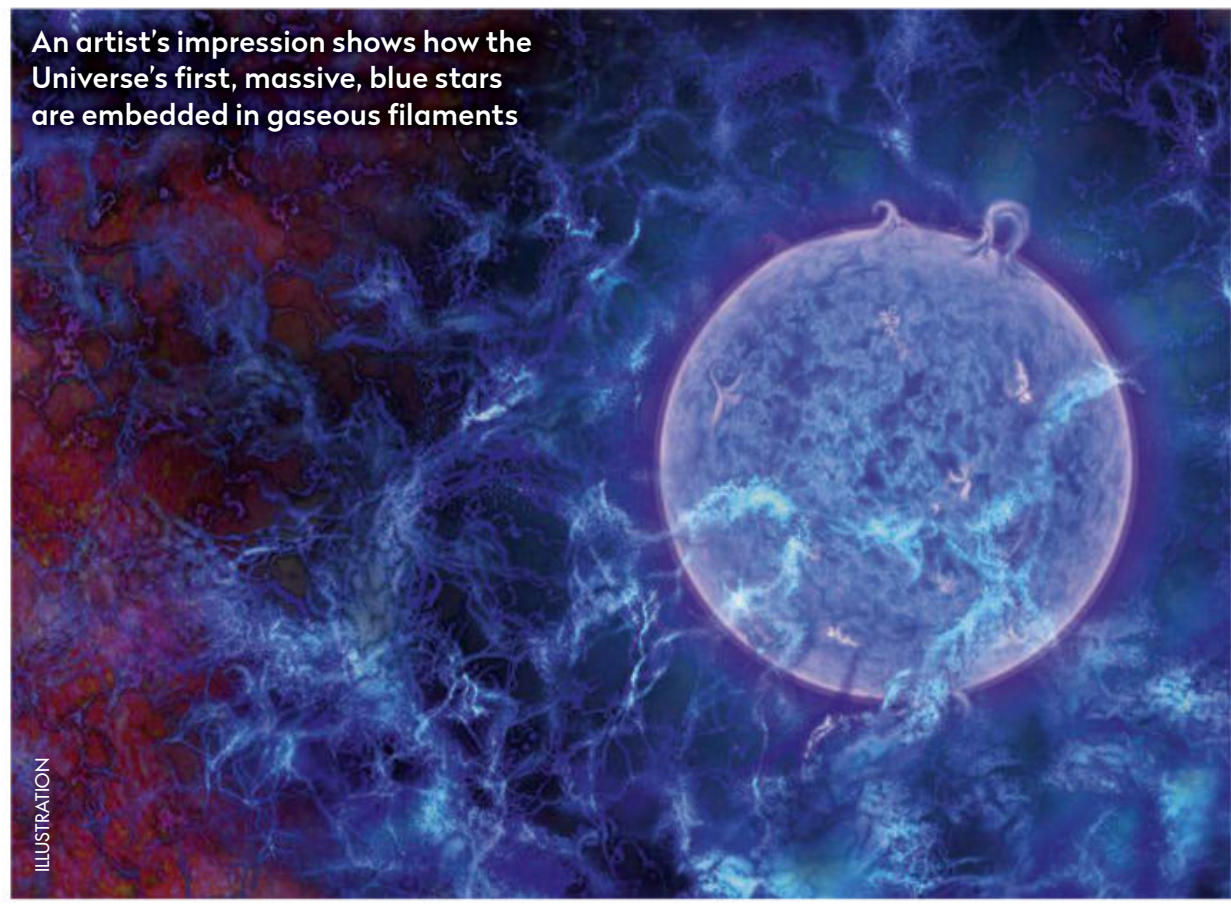
Computer simulations suggest that conditions in the early Universe, and in particular the absence of elements other than hydrogen and helium, favour the production of massive stars, but we need to test these models. Depending on which ingredients you tweak in your stellar recipe, it's easy to end up with a population of first stars where each weighs several hundred times the mass of the Sun, or a series of clusters of nearly Solar mass stars. A new paper, by astronomers in Heidelberg (Germany), Taipei (Taiwan) and Portsmouth (UK), suggests it might be possible to shed some light on the problem with the JWST; not by observing the stars themselves, but by finding the galaxies they called home.

The team use a code called ENZO to simulate how the Universe changes during the first few billion years of its existence. They compare the results from simulations where the masses of the first stars – known confusingly as 'Population III' – are different. It turns out you end up with a very different set of galaxies in each case, because these stars change their surroundings. Any surrounding material evaporates under their bright glare, and neighbouring gas is affected too. Their violent deaths as supernovae – the details of which depend very much on the mass of the star – scatter those heavy elements through the rest of the system, providing the raw material for the next generation of stars.

> ***"Computer simulations suggest that conditions in the early Universe favour the production of massive stars"***

Galaxies with more massive Population III stars produce normal stars more rapidly, which makes sense. The more massive early stars will burn through their fuel faster and explode as supernovae more rapidly. But the presence of a truly impressive set of first stars turns out to be a double-edged sword. The powerful supernovae churn up the gas throughout the small protogalaxy, preventing further galaxy growth. So, although such a system will shine brighter early on, it ends up fainter than a counterpart which starts with more modest stars.

This matters because whether the JWST can see the Population III stars themselves remains an open question. But unless something is really awry with our understanding of galaxy formation it definitely will be able to measure the properties of such protogalaxies. After decades of effort, the secrets of the first stars might be about to be revealed.



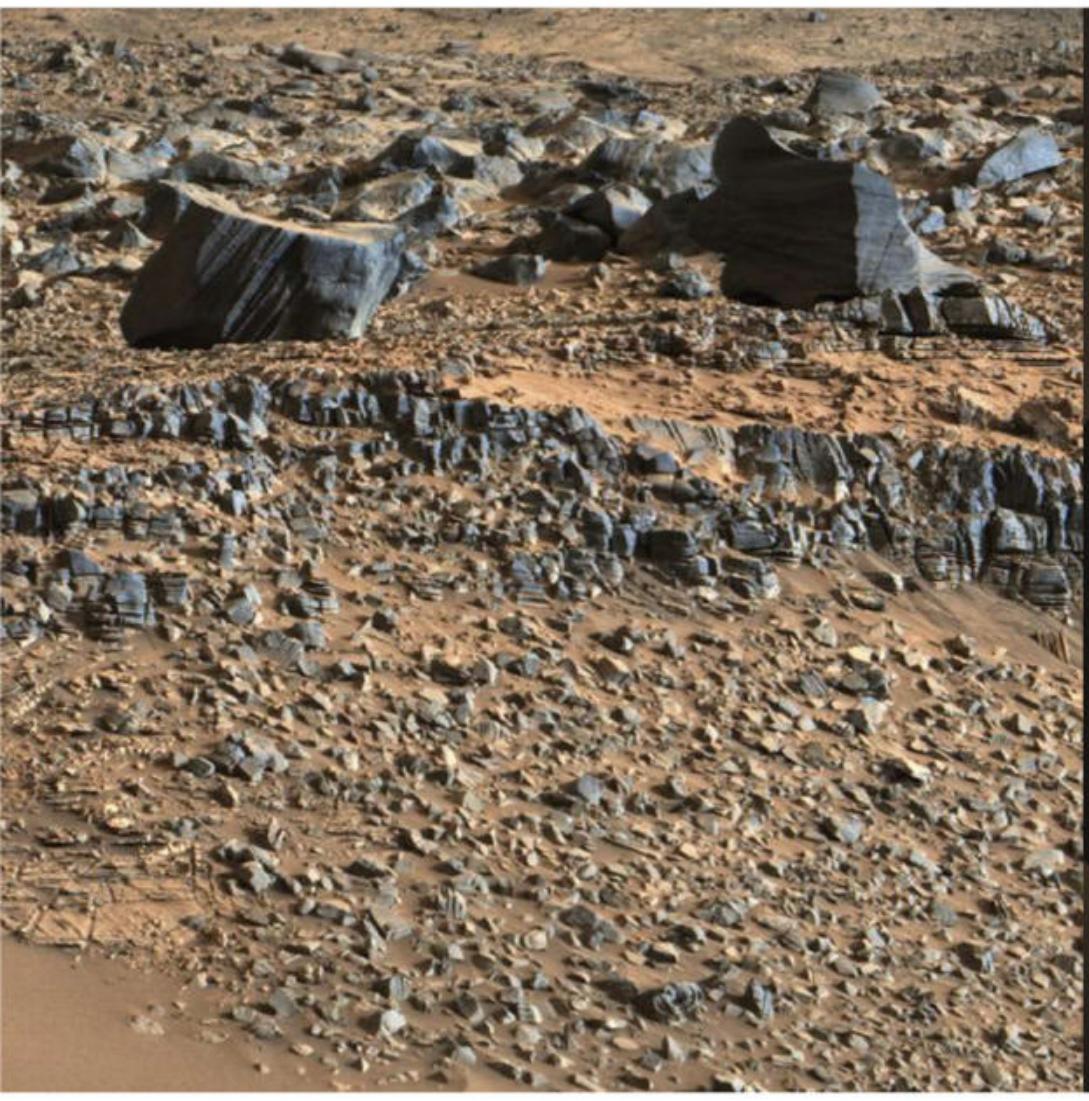
An artist's impression shows how the Universe's first, massive, blue stars are embedded in gaseous filaments

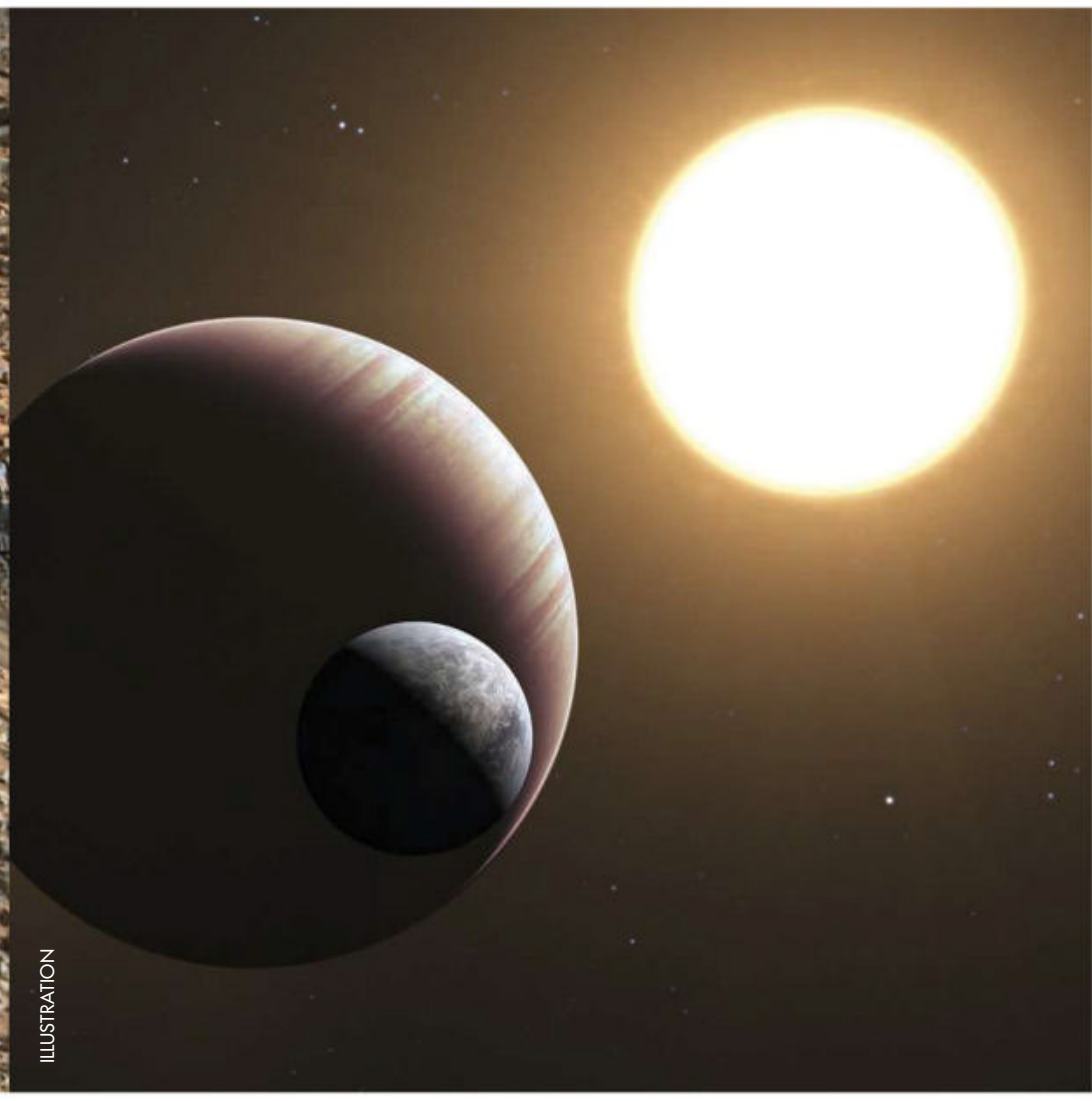
ILLUSTRATION

Chris Lintott was reading... *How the Population III initial mass function governs the properties of the first galaxies* by Li-Hsin Chen et al.
Read it online at: https://arxiv.org/abs/2010.02212

The Sky at Night TV show, past, present and future

INSIDE THE SKY AT NIGHT





NASA/JPL-CALTECH/MSSS, ESO/L. CALÇADA, ESO/M. KORNMESSER, BBC X 3, NASA

ILLUSTRATION

▲ **Searching for life: (Left:) NASA's Curiosity rover looked at the surface features of Mars for ancient traces of water**

(Right:) scientists are widening their search to the moons around gas giants

With recent news of a potential biomarker on Venus, *The Sky at Night* took a wider look for alien life. Astrobiologist **Louisa Preston** told the programme about other potential habitats in our Solar System

Back in September 2020, scientists revealed that they had found phosphine in Venus's atmosphere. On Earth, phosphine is only produced by life – either by humans in a laboratory or by anaerobic organisms – so could there be a habitable zone in Venus's cloud deck, home to a phosphine-producing type of hardy life form? Even as an optimistic astrobiologist, I feel this is an unlikely scenario; I expect that with further research we will discover that the phosphine is being produced by a weird, currently unexplained, geochemical or atmospheric process. There's also the possibility that the result could be an error in processing of the data – responsible scientists have to acknowledge that. Yet despite the current firestorm of speculation about the origin of this signal, it has reignited and rejuvenated interest in Venus; it has brought the hellish world, until now written of by astrobiologists, out from behind the shadow of Mars and reminded us that it is a planet which still deserves our attention.

Historically, the search for life elsewhere in the Galaxy has focused on the hunt for conditions we currently think necessary for life: a source of liquid water, energy and nutrients. From our experience observing Earth's biota, wherever there is water there is a good chance of finding organisms. This is one reason why the growing number of detections of liquid water across the Solar System has driven the search for extraterrestrial life to encompass multiple worlds. Although incredibly diverse, today we have but one example of life and a single template of a planetary body capable of supporting it – Earth. This astrobiological gold standard is blessed with a protective atmosphere and sits within the habitable 'Goldilocks' zone of the Solar System, allowing liquid water to pool on the surface, and support life.

Red Planet clues

Mars sits at the outer edge of this habitable zone; despite its present dry demeanour, the Red Planet used to have rivers and lakes running across its

Dr Louisa Preston is an astrobiologist, author and science communicator at the Natural History Museum in London

surface. In 2018 NASA's Curiosity rover detected organic matter preserved within 3 billion-year-old mudstones, proving that complex organic molecules would have been available for life for much of Mars's history. NASA's Perseverance rover (which is currently heading off to Mars) and ESA's Rosalind Franklin rover (due to follow in 2022) are both tasked with hunting through the Martian geological record for fingerprints of past microbial life. With these missions, there is a sense that we're finally within touching distance of discovering whether there was life on the Red Planet.

Recently, astrobiologists have taken to looking for life not just on planets, but at the moons orbiting them as well. It is now believed the gas giants have their own 'Goldilocks' zones – where water survives in subsurface oceans or hydrocarbon-rich lakes that decorate the surface. Both of these could provide a potential growing ground for organisms.

Although Venus might not be our first choice of astrobiological target, the revelations of the past few months have reminded us how little we know about our planetary siblings and how life has the potential to exist in even the most uninhabitable niches. Most importantly it has highlighted how vital it is that we keep exploring, as you never know who or what might be hiding in the most unlikely of places.

We need you!

Would you like to appear on *The Sky at Night*?

January 2021's episode of *The Sky at Night* will feature a number of notable guests, who will be invited to pick their favourite moment from episodes of the programme shown in 2020. They will each record a short clip explaining their choice and it will be broadcast alongside their chosen highlight.

The Sky at Night is also offering viewers the chance to be one of the invited guest contributors. All you have to do is write in with your favourite moment from the year and explain why you picked it. It could be for its scientific importance, or for the personal impact it had on you – did it make you laugh or cry, or inspire you or someone you know to look at the night sky? It could even be a moment that brought you relief or perspective during what has been a difficult year for many of us.

If you would like your selection for *The Sky at Night* Pick of the Year to be considered, send an email to: **skyatnightqt@bbc.co.uk**. Please include your name, address and a contact number.

▲ From stargazing, to observing Mars through the years, to possible life on Venus – what's your 2020 highlight?

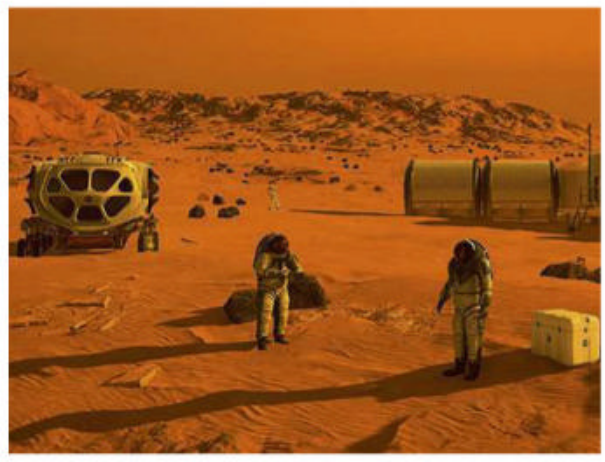
The Sky at Night

DECEMBER

The State of Astronomy

This one-hour special looks back at the last decade and its many major advances and discoveries in astronomy. The team also look forward to the next 10 years and the challenges and opportunities ahead. Joining Chris and Maggie will be an ensemble of UK astronomers including Astronomer Royal, Lord Martin Rees, to answer questions sent in by viewers.

BBC Four, **13 December**, 10pm (first repeat BBC Four, **17 December,** 7:30pm)
Check www.bbc.co.uk/skyatnight for more up-to-date information



▲ Will the coming decade see humans finally set foot on the Red Planet?

Emails – Letters – Tweets – Facebook – Instagram – Kit questions

INTERACTIVE

Email us at **inbox@skyatnightmagazine.com**

This month's top prize:
four Philip's titles

PHILIP'S **The 'Message of the Month' writer will receive a bundle of four top titles courtesy of astronomy publisher Philip's: Ian Ridpath and Wil Tirion's *Star Chart*, Robin Scagell's *Guide to the Northern Constellations*, Heather Couper and Nigel Henbest's *2021 Stargazing*, and a planisphere for the night skies as they appear at latitude 51.5° north.**

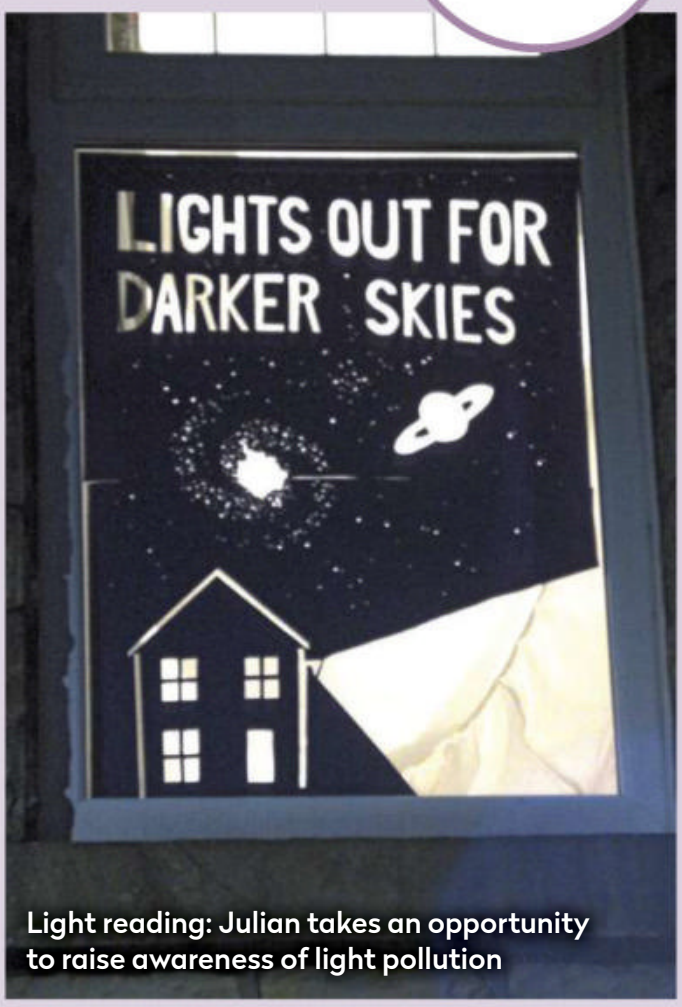
Winner's details will be passed on to Octopus Publishing to fulfil the prize

Lights out for darker skies!

My hometown has an excellent and popular annual September Festival, but this year the usual finale of a lantern parade was replaced by another event. In a phrase which would strike fear into the heart of any astronomer, residents were encouraged to 'Light Up New Mills!' This involved people putting up illuminated window designs for the weekend, so I decided to use the occasion for an opportune dark-skies message. I'm not expecting to see the M74 spiral galaxy from my back garden any time soon, but I hoped it raised awareness of the downside of too much light!
Julian Ashworth, New Mills

A fitting place for a message about the blight of light pollution, Julian. For those perhaps not familiar, M74 is one of the faintest targets in the whole Messier catalogue, hence its other name, the Phantom Galaxy. ***– Ed.***

MESSAGE OF THE MONTH

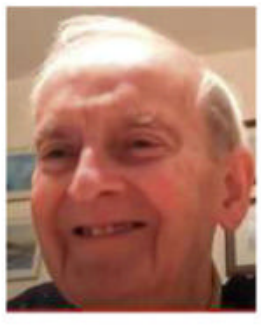


Light reading: Julian takes an opportunity to raise awareness of light pollution

Tweet

Pete Collins
@diamondskies99 • Oct 24
Derwentwater, #milkyway and me (oh, and an Iridium flare top right!) #darkskies #Cumbria @skyatnightmag @StormHour @FriendsofLakes @LakeDistrictPR @lakedistrictnpa

Fond farewell



It is with great sadness that we mourn the death of Eddie Carpenter. Introduced to astronomy by his father in Cornwall, Eddie was a staple member of the Bristol Astronomical Society since the 1980s. In that time he served on the committee. Among other roles he was vice-chairman and organised member talk nights. Most recently he was given lifetime membership of the society.

Eddie trained and worked as a teacher. He used those skills for the society too, educating us on the best astronomy books to read, astronomical anniversaries and, most recently, Cornish astronomers. Eddie discovered an asterism, which was published in the Saguaro Asterisms Database in 2013, and subsequently in *BBC Sky at Night Magazine* in 2014. The asterism is called Eddie's Roller Coaster and is located in Cassiopeia.

Always humorous, deep thinking, enthusiastic, eclectic, knowledgeable and insatiable in his desire to understand the cosmos, his lifetime's experience with astronomy – while amateur in tone – was exceptional in practice. He will be deeply missed and fondly remembered.
Fiona Lambert, Chair, Bristol Astronomical Society

Catching Mars

I was fortunate to be able to take some shots of Mars over about two hours at the end of September, before the

bad weather set in. Using my ZWO ASI120MC camera and FireCapture I was able take six lots of 2-3 minute videos before it drifted out of frame. After processing with AutoStakkert! and RegiStax, I was pleased with the results as I've recently had a total knee replacement and so could only roughly align my EQ5 mount and 8-inch Sky-Watcher telescope: it was struggle to manhandle them and I couldn't get down to polar align in the normal way. I managed to make a short GIF which clearly shows the planet's rotation – a first for me. I'm looking forward to catching Mars again when the weather improves.
John Consadine, Norfolk

Night sky fan

Here is my very first astro photograph (right). I took it early on the morning of 9 October 2020, from northwest London on a Canon Powershot SX500 IS that I found while I was rummaging at the back of a cupboard at home. I hope to study astrophysics when I am older. I love reading *BBC Sky at Night Magazine* and I watch both the modern and the archived *Sky at Night* TV programmes; my hero is Patrick Moore.
Sigal Nachshen (aged 11), via email ▸


11-year-old Sigal's picture of the Moon

ON FACEBOOK

WE ASKED: What do you do when bad weather rules out practical astronomy?

David Millar I have a play with Stellarium when it's cloudy and watch samples of the YouTube astro tutorials. There's so many interesting videos to help pass the time away.

Chloe Corfield I've given up, every time without fail it's either cloudy or raining – the perils of living in Scotland.

Mehmet Karagül My problem is with Istanbul's heavy light pollution, but ironically when there *is* a great astronomical event that I can see or photograph, the weather is bad.

John Owen Edgar I've got Sky Map app on my phone and my partner keeps coming into the living room to find me pointing the phone at the ceiling... or blank walls... or the floor... definitely not pretending I'm in Australia (I am). She thinks I've gone totally mad of course. On the plus side it is warm!

Joel Oxley I go on eBay and look at all the beautiful enormous telescopes that I'll never be able to afford!

Brian Dwyer Those astrophotos aren't going to process themselves.

David Loosemore I have been making myself a 3D-printed DSLR star tracker for my tripod, that I have modified from an excellent design from Thingiverse.

Nick Williams Grab my latest copy of *BBC Sky at Night magazine* and start planning what to observe/image when the weather finally improves; it will, won't it?

Rehman Abubakr I research and record upcoming celestial events visible from my country, Sri Lanka, and keep going into the future, depending on the amount of time I have.

Tony Greenhead Monopoly...lol

SCOPE DOCTOR

Our equipment specialist cures your optical ailments and technical maladies

With **Steve Richards**

Email your queries to
scopedoctor@skyatnightmagazine.com

My son and I have a 10-inch Dobsonian telescope. What types of eyepiece would be suitable for deep-sky objects, are Plössls good?

MICHAEL RANGER

▲ Recommended: BST StarGuider eypieces (right) are a good budget option, while Pentax XW eyepieces give excellent results

Plössl eyepieces are a relatively simple design with an apparent field of view of 50°–52°, but just because they're simple it doesn't mean they aren't any good. However, the Plössls that come bundled with telescopes are often of relatively low quality, especially the shorter focal length variants.

Assuming your 10-inch Dobsonian mount has a focal ratio of f/5 or faster, you'll need to choose eyepieces carefully, especially if you're looking for wider fields of view. At the budget end, the BST StarGuider range with their 60° apparent field of view would be a good choice; in either 15mm or 18mm focal length for general observing, and 8mm and 5mm for more magnified views of planetary nebulae and globular clusters.

In the shorter focal lengths of 5mm, 7mm and 10mm, eyepieces from the Pentax XW range with their 20mm eye relief and 70° apparent field of view would also be an excellent choice to consider.

Steve's top tip

What are RGB filters used for?

Colour images are made up of data collected using red, green and blue (RGB) filtering. On a 'one-shot colour' camera like a DSLR or colour astro camera, tiny filters are built into the sensor surface, but if you're using a mono CCD or CMOS camera, the filters have to be introduced externally. Usually, red, green and blue filters are held in a filter wheel that will allow you to capture a series of images. These images are then stacked in their colour groups and combined in processing software to produce a single RGB colour image.

Steve Richards is a keen astro imager and an astronomy equipment expert

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IMMEDIATE MEDIA Co

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▲ **A selection of Andrew's magnificent oil on canvas paintings**

Cosmic art

▸ I am a big fan of your outstanding magazine, and thought I'd send you some images of my new oil-on-canvas paintings. I am an artist and have designed book covers for Stephen Hawking, Carl Sagan and the great Heather Couper.
Andrew C Stewart, Nottingham

CORRECTIONS

In the entry for Mercury in 'The Sky Guide' on page 48 of the November 2020 issue, it is Mercury that "...maintains a good brightness, shining at mag.–0.7 on the 30th and rises an hour before sunrise", not Neptune as printed.

Instagram

from.paddington • 22 October

Last Thursday I was out early on a walk at sunrise. The moon, a waning crescent, was not long risen. However, it looked unusual as the rest of the Moon was also visible with a yellowish hue.
A little research revealed that this phenomenon is called 'Earthshine', sunlight reflected off Earth dimly illuminating the night side of the Moon. It is most readily noticeable a few nights before or after a new Moon and shortly before sunrise or after sunset.
I haven't noticed it before but I will be looking out for it again in future.
#moon #waningcrescent #waningcrescentmoon #purbeck #dorset @bbcskyatnightmag

SOCIETY IN FOCUS

Like all astronomy societies, the **Astronomical Society of Glasgow** (ASG) has had to adapt rapidly to COVID-19 restrictions. Like many others we did this by entering the virtual domain and the society's council continued to work behind the scenes to serve our members.

We set up an expanded monthly lecture programme on a diverse range of subjects, including astrophysics, planetary science, astrobiology and space exploration. This is running concurrently with monthly virtual astrophotography group meetings and beginners' classes. The ASG has explored the feasibility of running socially distanced observing evenings at our main out-of-town site at Mugdock Country Park, but these still remain uncertain.

Mugdock has also been the focus of a major project to construct the Eric Tomney Memorial Observatory. After several years of planning and legal work, efforts to build the facility have stepped up and despite

▲ **Visit the website of the Astronomical Society of Glasgow for updates on its events**

the inevitable COVID-19 delay, the society remains confident we will have a fully equipped observatory for use by our members when better times return.

The ASG continues to welcome anyone interested in becoming a member: we cater for all levels of interest and assume no prior knowledge of astronomy. See our website for details of our lecture and events programme and how to join.
David Degan, Secretary, Astronomical Society of Glasgow
▸ **www.theasg.org.uk**

COVID-19

Socially distanced and online events this month

Our pick of the best events from around the UK

WHAT'S ON

Outdoor film experience

OM Dark Sky Park and Observatory, Omagh, until March

Wrap up warm for a journey through space and time via a film projected onto the outside of Northern Ireland's brand new OM Dark Sky Park and Observatory. Guided tours of the new attraction are also available. The events run every day until March and you can book tickets at **bit.ly/omdarksky**

Cambrian Mountains stargazing weekend

Staylittle, mid Wales, 11–13 December

Stay in a deluxe cabin and enjoy two days of astronomy tuition, observation and astrophotography under some very dark skies. The weekend costs from £374.35 per cabin (up to four people). Book at **bit.ly/darkskywalestraining**

Night 'awe-walk'

Urra Moor, North Yorkshire, 13 and 14 December 2020, 4pm

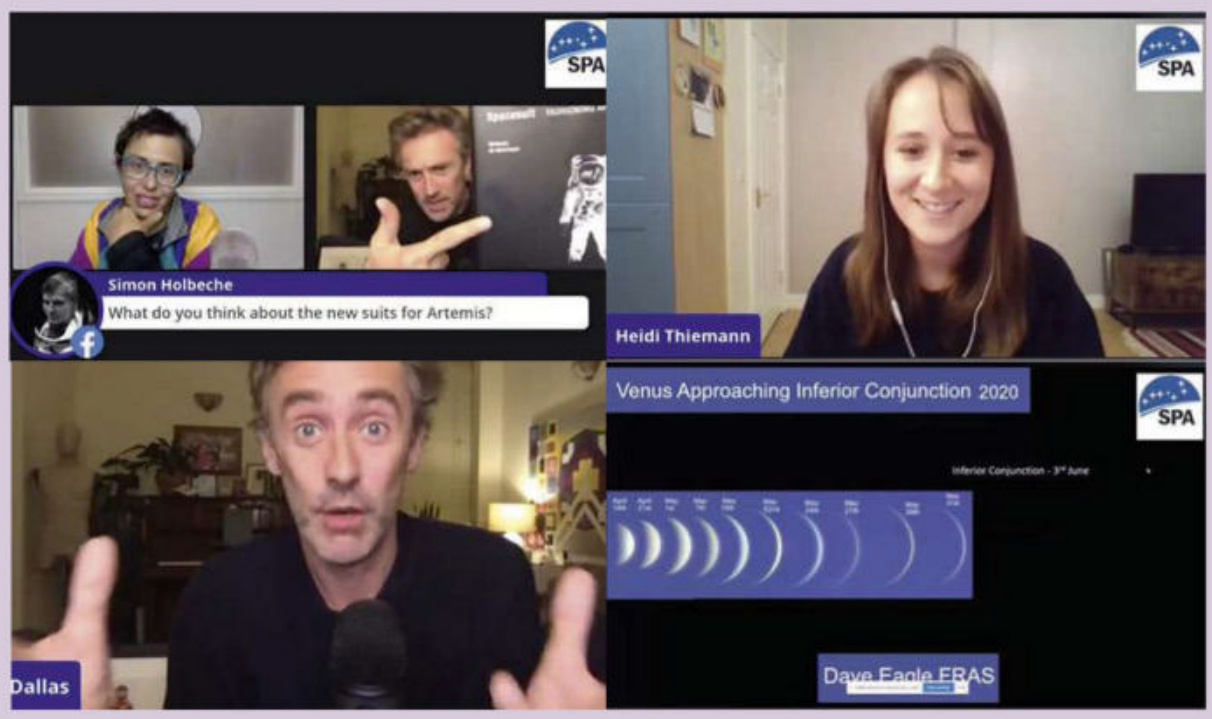
Join a small, socially distanced group for a guided walk around the highest point in North York Moors National Park, with a chance to catch the Geminids. £45 per person. Book at **www.adventuresforthesoul.co.uk/geminids-meteor-shower**

Have a Geminids mini party

The peak of the Geminids meteor shower falls around 13/14 December. With no Moon to spoil the show, why not plan a night of COVID-safe meteor spotting with a friend? Get comfy with sleeping bags and sunloungers, and remember to take plenty of snacks and hot drinks. If you want to record your sighting, follow our guide here: **bit.ly/observegeminids**

IOM DARK SKY PARK AND OBSERVATORY

PICK OF THE MONTH



▲ **Expert views: enjoy a wide range of PopAstro Live videos on all things astronomical**

PopAstro videos

Online astro chat with the Society for Popular Astronomy (SPA)

Adapting to these challenging times, the Society for Popular Astronomy (SPA) has embraced the virtual life with a host of interactive PopAstro Live videos. Hosted by Vicky Duncalf and featuring a variety of guests, recent topics include: diversity in astronomy with Heidi Thiemann from the Open University and Lucy Williams from the RAS; the science of space suits with Dallas Campbell and Stephen Wisdom; Alice Sheppard talking about citizen science projects; a radio astronomy special with Dr Anna Bonaldi; and a life on Venus special with Dave Eagle, Nigel Henbest and Dr Chris North. For newsletters, magazines and support, you can join the SPA from £23 a year. To find their videos, search 'Society for Popular Astronomy' on Facebook and visit **youtube.com/c/popastro/videos**

Stargazing and aurora

The Twice Brewed Inn, Hexham, 29 and 30 December

This pub in Northumberland's International Dark Sky Park hosts a socially distanced talk about aurorae and how to spot them, followed by an observation session. It costs £48 for stargazing and supper, or £139 with a night's stay at the Inn. Other stargazing events are available too. Book at **bit.ly/stargazingandaurora**

WHAT'S ONLINE

The Antikythera Mechanism

Hampshire Astronomical Group is delighted to be holding public lectures again, albeit via Zoom. Join them for a programme of free talks, kicking off on 11 December at 7.30pm with one by John Lancashire on the ancient Greek astronomical prediction machine, the Antikythera mechanism. Book a place by contacting **lindy.bryant@hantsastro.org.uk**

Thank you, Sylvia

Sylvia left a gift in her Will to help conquer Stroke

The first we knew of Sylvia was when we received notification of the gift she'd left us in her Will. Shortly after, a beautiful story of a much-loved woman began to unfurl.

Friends remembered Sylvia's kind-heart and her wish to help others. She spent part of her adult-life caring for her mother, and developed a passion for medicine. Becoming a medical secretary was her next step and, in the course of her career, she discovered the devastating impact a stroke could have on people and their families. She saw that research and treatment were vastly under-funded, and she decided to remember the Stroke Association in her Will.

Sylvia's gift has helped fund our work to conquer stroke. She's supported research to prevent and treat stroke, and she's helped care for survivors. And that's something you can do too – in the same way.

If you would like to learn more about remembering the Stroke Association in your Will, please get in touch.

Call 020 75661505 email legacy@stroke.org.uk or visit stroke.org.uk/legacy

Stroke association

FIELD OF VIEW

"...things in heaven and earth..."

Ahead of 21 December, Jane Green looks at literary conjunctions across the ages

Jane Green is an astronomy writer and author of the *Haynes Astronomy Manual*

Will this month's Great Conjunction of Jupiter and Saturn on the 21st improve your love life, or your career? Will there be thunderbolts and lightning and other very, very frightening things? Does its apparition herald a new messiah or monarch? War, flood, famine, plague and pestilence? Like astronomers – and astrologers – of centuries past, feel free to associate your own pattern of events to this super-close alignment.

Celestial alignments have excited, inspired, 'influenced' and frightened humanity throughout history. This 'conjunctionitis', as I call it, has resulted in predictions and interpretations in literature too.

Aristotle, in his work *On the Causes of the Properties of the Elements*, comforted readers by assuring them that Jupiter and Saturn conjunctions caused "mortality of races" and "depopulation of kingdoms".

Later, Arab astrologer Albumasar wrote in his *De magnis conjunctionibus* (886) of three conjunctions of Saturn and Jupiter: the 'great one', a 'greater' and 'the greatest', each occurring over longer epochs respectively. For centuries this influenced Christians, among them the scholastic thinker Roger Bacon, who took up the conjunction cudgel in his *Opus Majus*.

In the Middle Ages, Italian poet and astrology sceptic Dante Alighieri acknowledged a preoccupation with the configuration of stars and earthly events below. He was anticipating a Messiah to purge Christianity, the religious establishment, of its evils. In the latter part of his *Purgatorio* (XX.13-15 and XXXIII.40-45) he made a passing reference to a conjunction. But it was his son, Piero, who imagined that this was a prophetic reference to the conjunction of Saturn and Jupiter (along with Mars) in 1345, 24 years after Dante's death in 1321. Again, feel free to interpret at will!

And staying with Will, the great bard himself, Shakespeare, employed numerous astrological, nay, astronomical references in his works, and these also included a few planetary conjunctions. In *Henry IV, Part II*, Prince Hal proclaims, "Saturn and Venus this year in conjunction! What says th'almanac to that?" But this celestial observation was somewhat carnal in nature: a metaphor for Falstaff kissing a prostitute with the unfortunate moniker Doll Tearsheet!

Shakespeare's characters often professed undying love when planets 'cosied up' in the zodiacal belt: Claudius for Gertrude in *Hamlet*, whose love was "so conjunctive to my life and soul"; Queen Margaret for Suffolk in *Henry VI, Part II*, his "lovely face" ruling "like a wandering planet" over her. Both were references to planetary conjunctions. We can only imagine the literary fireworks ignited when Jupiter and Saturn 'kiss' on 21 December 2021!

Perhaps this time the gas giants' 'meeting' will be more agrarian in nature, as penned by WB Yeats in his poem *Supernatural Songs*. "If Jupiter and Saturn meet, What a crop of mummy wheat! The sword's a cross; thereon He died. On breast of Mars the Goddess sighed." Saturn, with his sickle, is often portrayed as the grim reaper; conversely, Jupiter embodies fruitfulness and generosity – yin and yang, harvest and growth, mummery or mumbo jumbo? You decide!

But however bad your 'conjunctionitis', whatever known or unknown influences emanate from the sky, be sure to step outside later this month and try to catch the historic Great Conjunction for yourself this winter solstice.

OLIVIA WALLER/FOLIO

BBC

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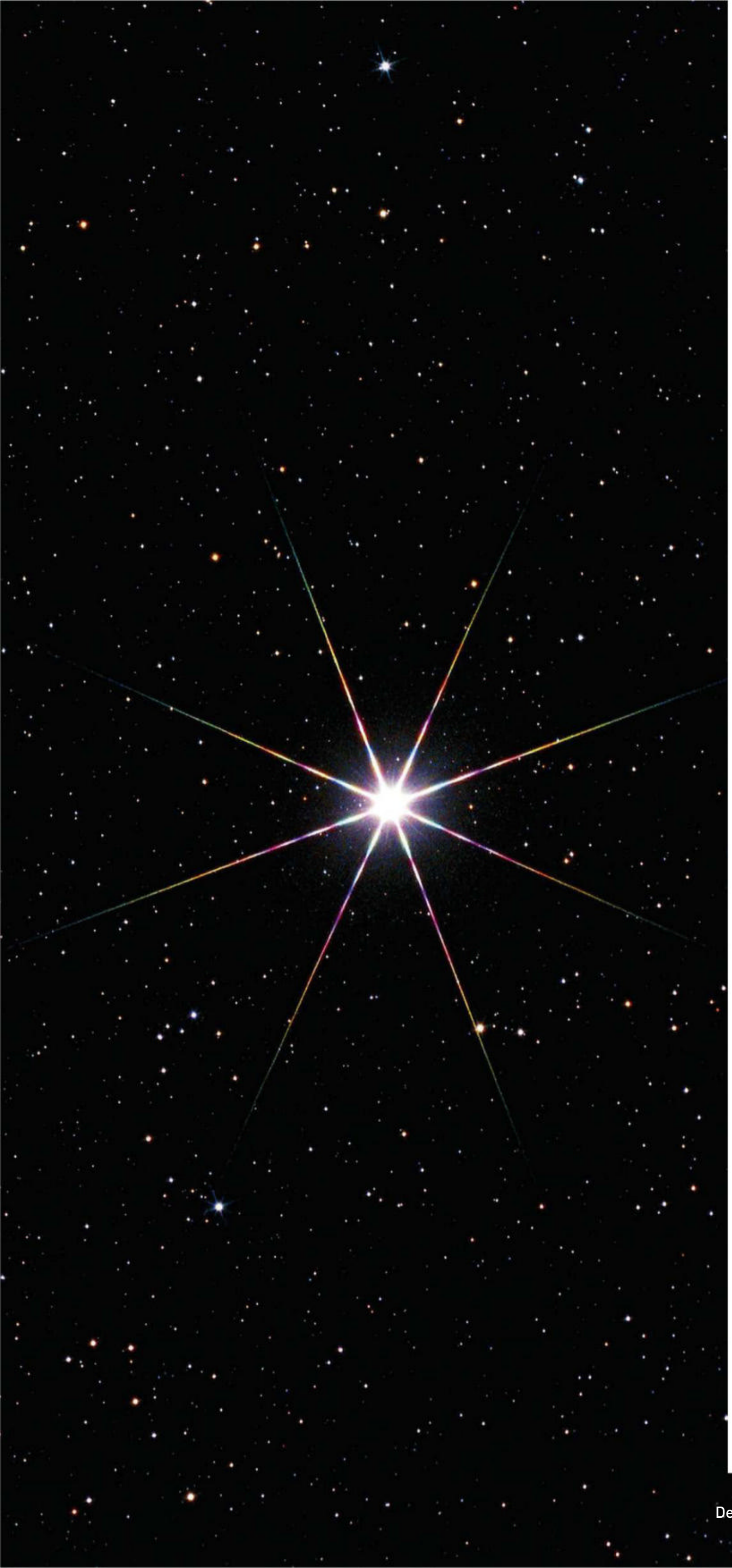
BBC Sky at Night MAGAZINE

THE GREAT CONJUNCTION:

history in the making

This winter solstice, the constellation of Capricornus will play host to the closest approach of Jupiter and Saturn of the telescopic age. **Neil Norman** looks at what gives the event its historic proportions



◄ Getting close: Saturn (middle left) and Jupiter (middle right) photographed in 1999 from California. This year they will get much, much closer

The winter solstice on 21 December is the beginning of astronomical winter for the Northern Hemisphere, and many like to witness or capture the rising and setting of the Sun on this, the shortest day. Astronomers have been anticipating this year's winter solstice (quite literally) for decades, not because of the solstice itself, but because of the planetary show that will be visible just after the Sun has gone down – to some it may be the greatest astronomical event they witness in their lifetimes.

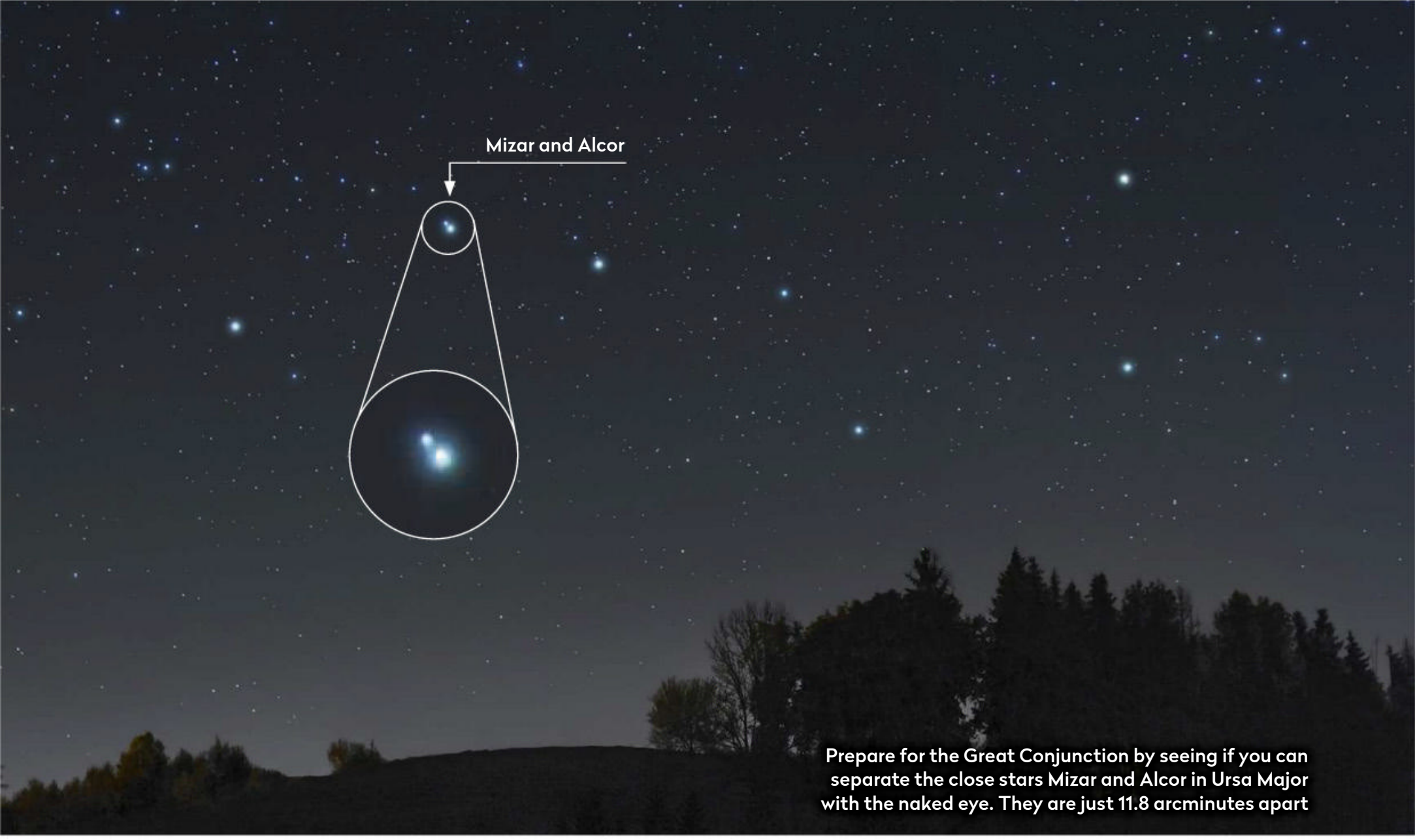
On 21 December this year the two behemoths of our Solar System – Jupiter and Saturn – will be coming together in what astronomers call a 'Great Conjunction', appearing to the naked eye for many as a single bright 'star'. Indeed, this year's event is no ordinary one – it will be the closest such conjunction since 1623.

Drawing near

On this evening Jupiter and Saturn conclude their 20-year conjunction cycle, a repeating pattern of close approaches that comes about due to the combination of Jupiter's 11.86-year orbital period and Saturn's 29.5-year orbit. Amateur astronomers love to observe a planetary conjunction, and they can be relied upon to capture the attention of the general public as well: the closer the objects the better, as these create attractive images and lasting memories. Conjunctions don't get much closer than on 21 December when Jupiter and Saturn (lying some 30° east of the Sun in Capricornus) will be separated by just one-tenth of a degree, or 6.1 arcminutes.

The question is, will you be able to make them out individually with the naked eye? To test whether you might, take a look at the Mizar-Alcor pairing in Ursa Major. The stars Mizar (Zeta (ζ)Ursae Majoris) and Alcor (80 Ursae Majoris) are separated by 11.8 ►

JOHN SANFORD/SCIENCE PHOTO LIBRARY



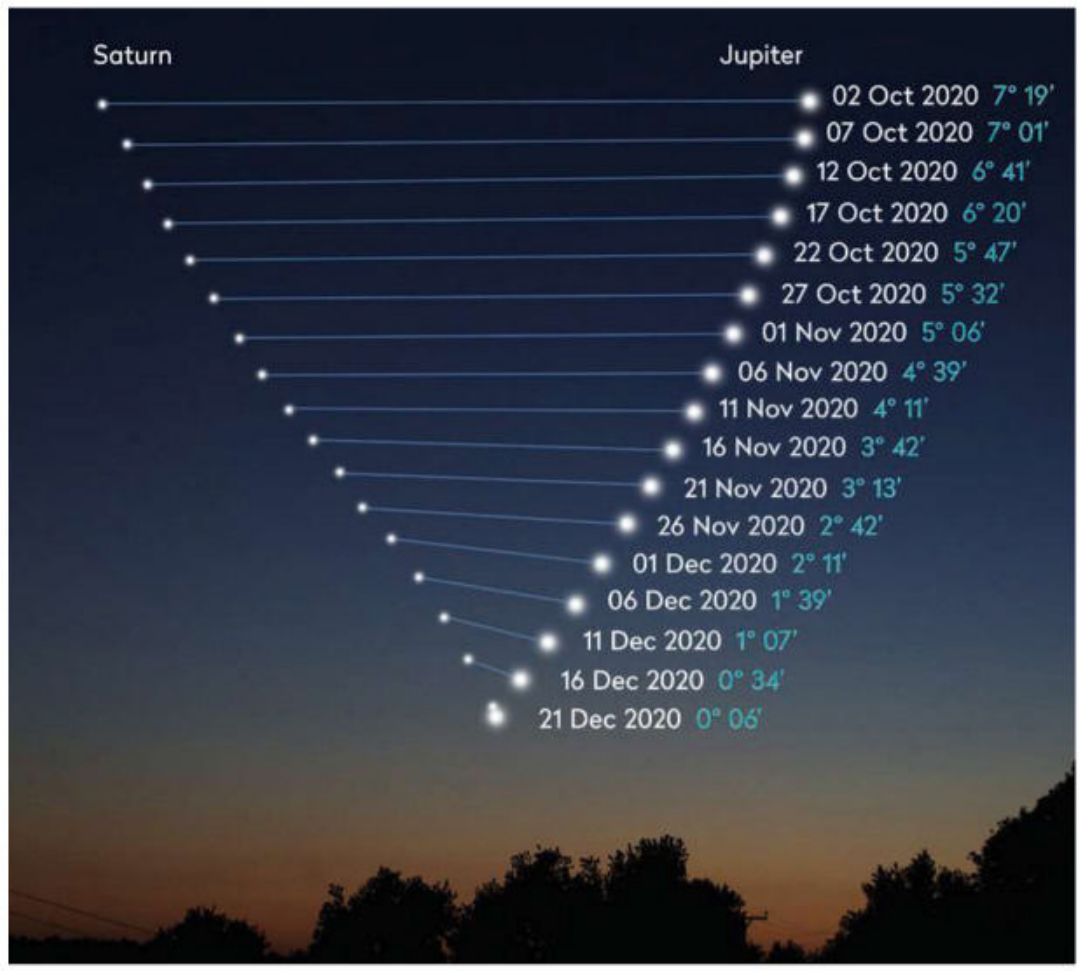
Prepare for the Great Conjunction by seeing if you can separate the close stars Mizar and Alcor in Ursa Major with the naked eye. They are just 11.8 arcminutes apart

▸ arcminutes and are traditionally used as a test of an observer's eyesight. With that in mind, you can see just what kind of challenge we face. The other challenge faced on the 21st will be the height of the Jupiter–Saturn pairing above the horizon: you will need every degree of sky you can find because even at sunset (15:53 UT), the planets are just over 14˚ high and sinking quickly towards the horizon. So choose an observing site with a clear southwest horizon and keep your fingers crossed for good seeing in that direction. However, observers of this historic event will have one thing in their favour, the fact that the pairing will be shining brightly against a twilight sky – Jupiter at mag. –1.97 and Saturn at mag. +0.63.

Twilight viewing

As civil twilight begins at 16:28 UT, the Great Conjunction will be just 11˚ in elevation. With the Sun 6˚ below the horizon, now is the time to begin sweeping with a good pair of binoculars or a small telescope – there is no time to waste! Nautical twilight begins at 17:11 UT and the planets are now 7˚ above the horizon, becoming a challenge to view as darkness approaches fast. As darkness falls in its entirety at 17:52 UT, the planets are all but gone at just 2˚ in elevation and those lucky enough to have a clear horizon will see the pairing at their best. Those at more southerly latitudes will have the benefit of these stages occurring earlier, with the Great Conjunction higher in the sky the nearer to the equator you go.

Wherever you are on Earth, the best views of the conjunction will be in binoculars or a small telescope, as these will position both planets nicely in the field of view. With their increased magnification and wide field, large binoculars like 20x80s are ideal; they will show the shape of Saturn and also reveal some of Jupiter's markings, plus the four Galilean moons.

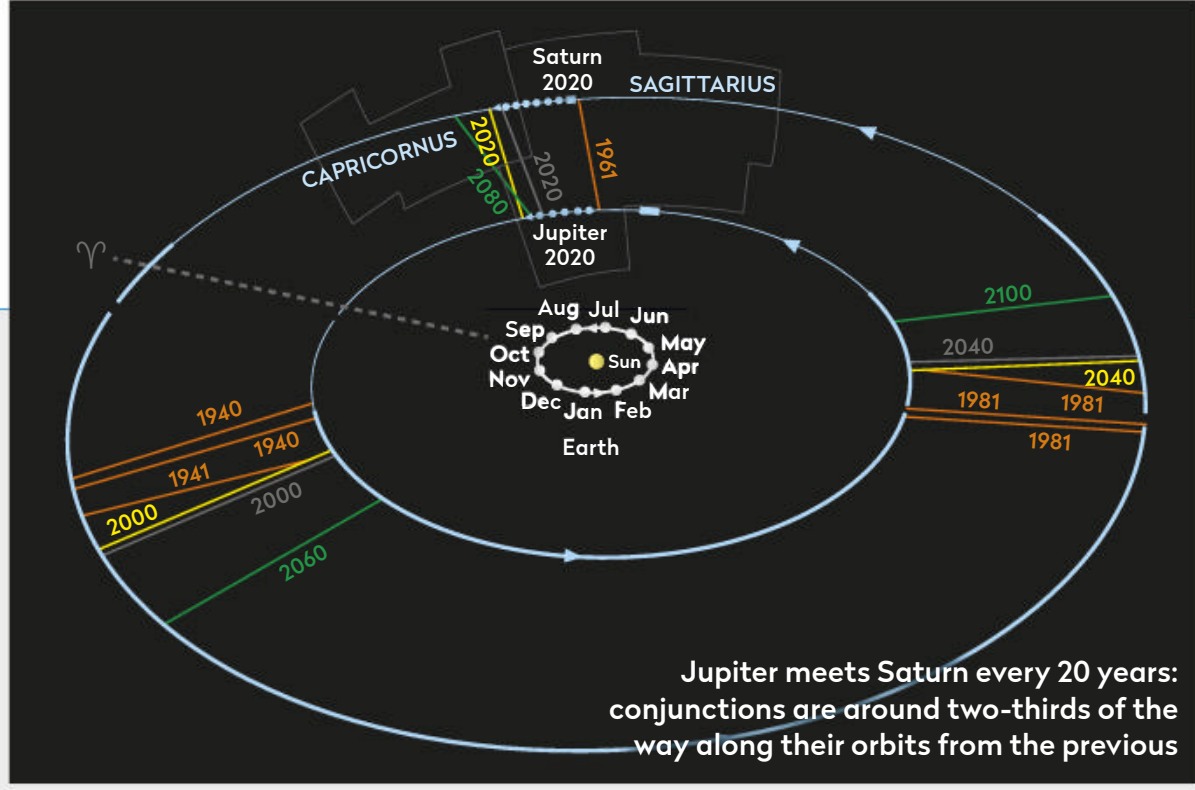


▲ Degrees of separation: Saturn and Jupiter close in on each other up to the Great Conjunction on 21 December (apparent distance given in degrees and arcminutes)

As an aside, it is interesting to note that at 17:52 UT on the 21st, the moons Io and Ganymede will appear to almost occult each other – an extra treat for those still able to view.

With Great Conjunctions occurring on a 20-year cycle, you might think that there will be another chance to view the spectacle in the coming decades. But not all Great Conjunctions are the same when it comes to the apparent separation of Jupiter and Saturn. In the December 1821 Great Conjunction, for example, Jupiter and Saturn were over a degree apart – the largest separation between the two planets between 1800 and 2100 (see table, right).

RASTAN/ISTOCK/GETTY IMAGES, C HARTS BY PETE LAWRENCE



Jupiter meets Saturn every 20 years: conjunctions are around two-thirds of the way along their orbits from the previous

What is a Great Conjunction?

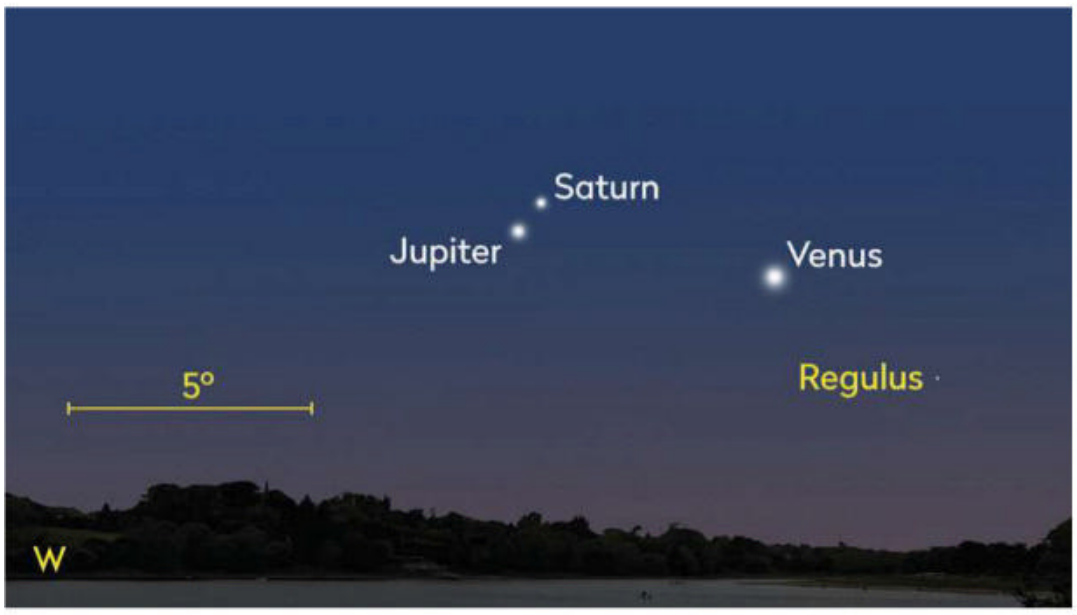
Why this winter solstice's conjunction is so special, and why it will go down in the annals of astronomical history

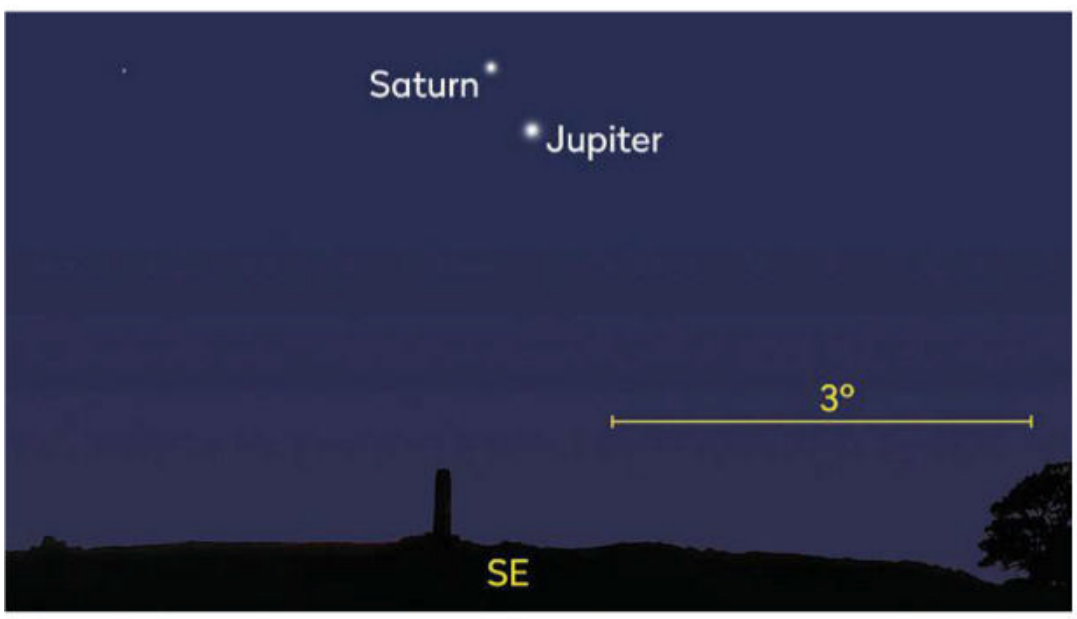
The year 2020 will be one that many of us will be forgiven for wanting to forget but in astronomical terms it will end in a blaze of glory, with one of the rarest and most unmissable sights in the heavens, a 'Great Conjunction'.

Great Conjunctions are once-in-a-generation events that occur on average every 19.6 years ,and involve the visually close pairing of the two giants of the Solar System, Jupiter and Saturn. This phenomenon, of course, is just a line of sight effect as viewed from Earth, but it is nonetheless a spectacular sight.

These conjunctions happen so rarely because of the leisurely journey both Jupiter and Saturn take as they orbit the Sun, with Jupiter taking 11.86 years and Saturn taking 29.5 years respectively. Each Earth year, Saturn completes approximately 12° of its orbit around the Sun, while Jupiter completes 30° of its orbit in the same time. We can calculate that Jupiter catches up to Saturn by 18° each year (30° – 12° = 18°), and that over a period of 20 years Jupiter gains a full 360° on Saturn (18° x 20° = 360°), bringing the two planets into apparent proximity.

Not all conjunctions are equally as close, though. While this year's Great Conjunction has a separation of just 0.1°, the next one to come around, on 31 October 2040, will see the two separated by 1.1°, making the 2020 winter solstice Great Conjunction a truly historic event.





▲ (top) A simulation of the Great Conjunction from 21 July 1802...

...and (below) from 25 January 1842

Out of that period of three centuries there were three 'triple conjunctions', when the two planets meet each other three times over a short time period. Triple conjunctions happened in 1821, 1940-41 and 1981, but the next one won't take place again until 2223.

Many of the Great Conjunctions from 1821 to 2000 have been less optimal, with over a degree in separation or being unobservable (see table, below).

DATE OF GREAT CONJUNCTION	SEPARATION OF PLANETS (DEGREES & ARCMINUTES)
25 June 1821	1°15'
22 November 1821	1°20'
23 December 1821	1°22'
22 April 1881	1°18'
14 September 1921	1°02'
15 August 1940	1°15'
11 October 1940	1°17'
20 February 1941	1°21'
14 January 1981	1°09'
19 February 1981	1°09'
30 July 1981	1°12'
31 May 2000	1°11'

▲ Great Conjunctions that have taken place from 1821 to 2000 with over a degree of separation

Still, in our 300-year timeframe (1800-2100), there are plenty of occurrences when Jupiter and Saturn have under a degree of separation. Let's take a closer look at them, starting with the Great Conjunction of 21 July 1802 (see simulation, left, above). This was visible after sunset in the constellation of Leo, with the two planets having an elongation (angular distance) from the Sun of some 38°. The separation between the planets was 42 arcseconds, with Jupiter lying beneath Saturn. Also in the vicinity was the planet Venus, 5° to the west, closer to the star Regulus (Alpha (α) Leonis), which would have made for a striking set of circumstances. ▸

Johannes Kepler and the Star of Bethlehem

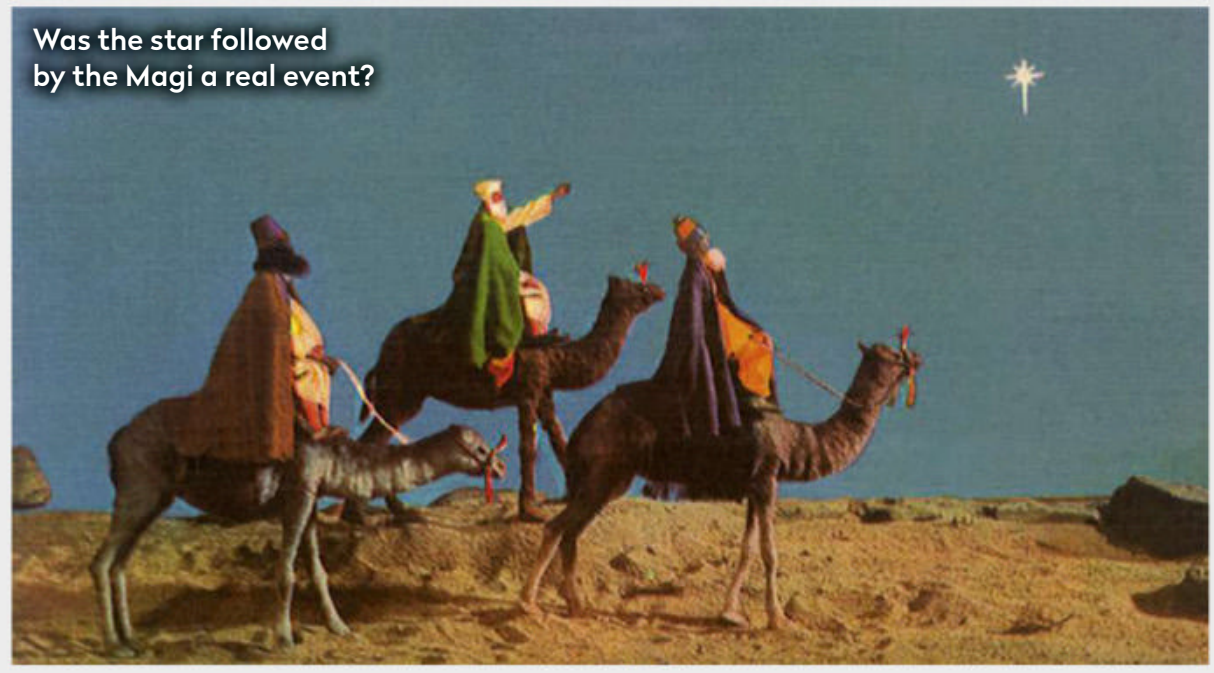
Alongside his laws of planetary movement, Kepler investigated the story of the Christmas Star

The Star of Bethlehem is a mystery still debated today among astronomers and scholars alike. Many theories for it have been put forward but none have been proven with any great confidence. However, one stands out as a good candidate – a planetary conjunction, or more precisely, a Great Conjunction.

This was the cause put forward in 1603 by the great German astronomer and mathematician, Johannes Kepler, after he had observed a Great Conjunction himself. Today, we know of Kepler because of his groundbreaking work on the orbits of the planets and his three laws of planetary motion published in 1609 and 1619, but he was also an accomplished astrologer.

It was this, coupled with his own Christian beliefs that led to his fascination with the true identity of the Star of Bethlehem. He began to wonder if the 'star' the Magi followed in the story of the nativity was actually a conjunction of Jupiter and Saturn, and soon began work tracking the planets' motions backwards through space and time to see if a plausible event could be found.

He came to the conclusion that the giant planets were indeed in conjunction in the year 7 BC, in the constellation of Pisces, with a separation of a degree at best. And this happened not just once but three times, on 27 May, 6 October and 1 December. The genius of Kepler may hold the answer to one of Christianity's biggest mysteries.



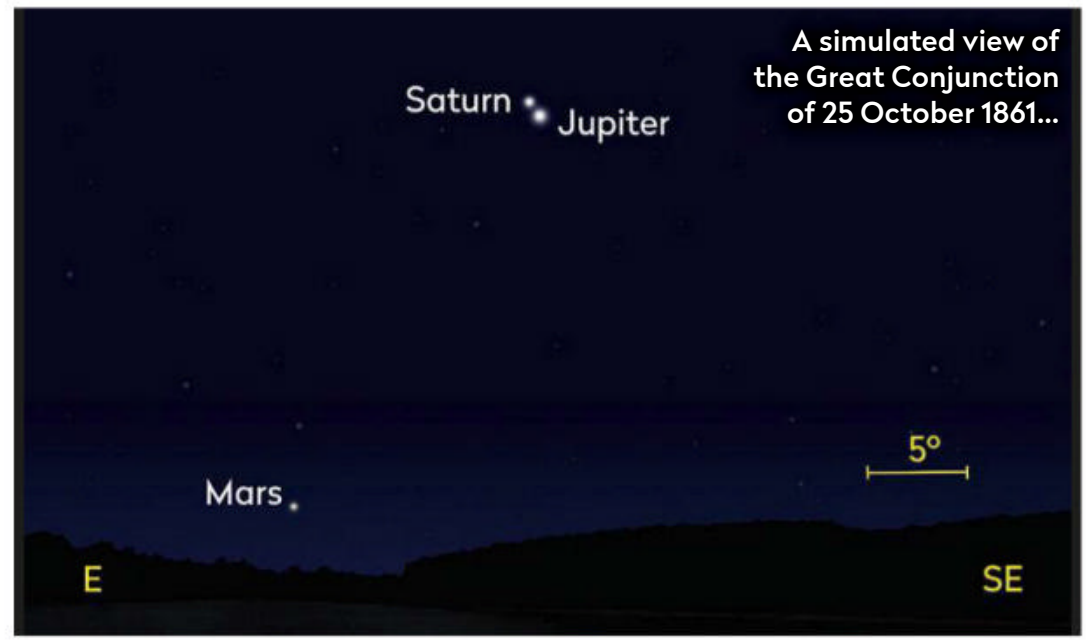
Was the star followed by the Magi a real event?

▸ On 25 January 1842 (see simulation at the bottom of page 32) the duo were separated by 32 arcseconds, with Jupiter again lying to the south of Saturn, this time within the constellation of Sagittarius and close to M22, the elliptical globular cluster of 5th magnitude. The elongation west from the Sun of this apparition was just 27˚ and so only a brief observational period of an hour would have been available. The Great Conjunction of 25 October 1861 (see simulation, right, above) was more favourable, however, with an elongation from the Sun of 43.1˚. The Jupiter-Saturn pairing rose four hours before the Sun in the constellation of Leo, with a separation of 52 arcseconds, Jupiter again south of Saturn.

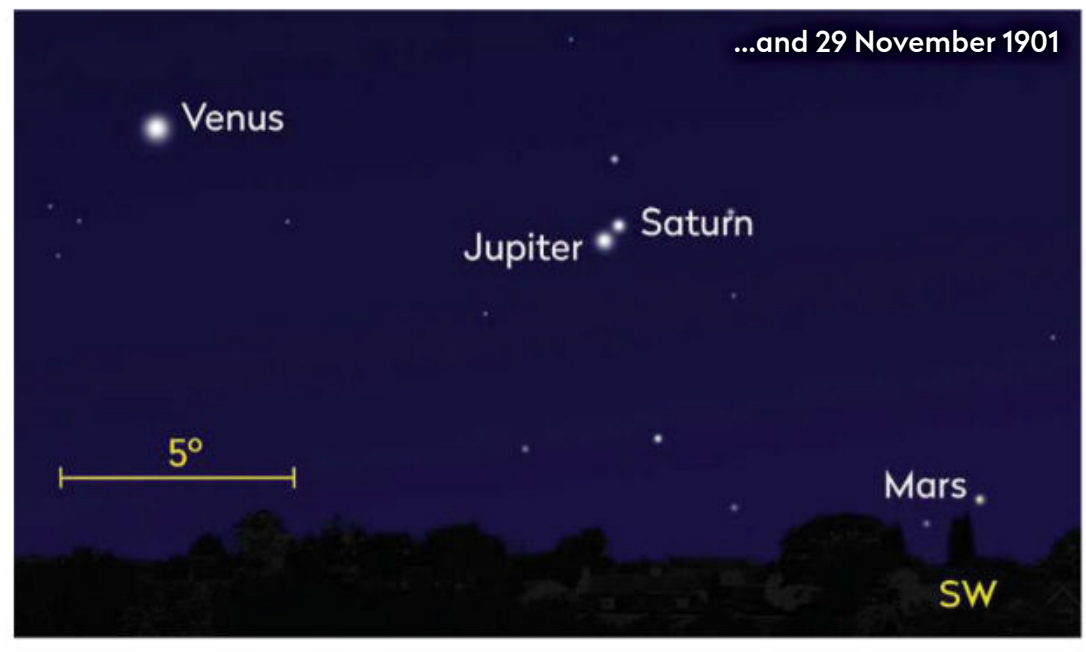
Venus put in another close appearance, 10° to the east on the first Great Conjunction of the 20th century (see simulation, right, below), while Mars, positioned 10° to the west, would have made 29 November 1901's event more appealing still. This conjunction occurred again in Sagittarius, with a solar elongation of 40˚ and Jupiter again to the south of Saturn, separated by some 27 arcseconds. The apparition was only brief, though, with just two hours of observation after sunset.

More recent encounters

Some 60 years after the Great Conjunction of 1901, the giant planets came together in the constellation of Sagittarius close to the 9th magnitude globular cluster M75 on 18 February 1961. This time solar elongation was 35˚, with the planets separated by 14 arcseconds.



A simulated view of the Great Conjunction of 25 October 1861...



...and 29 November 1901

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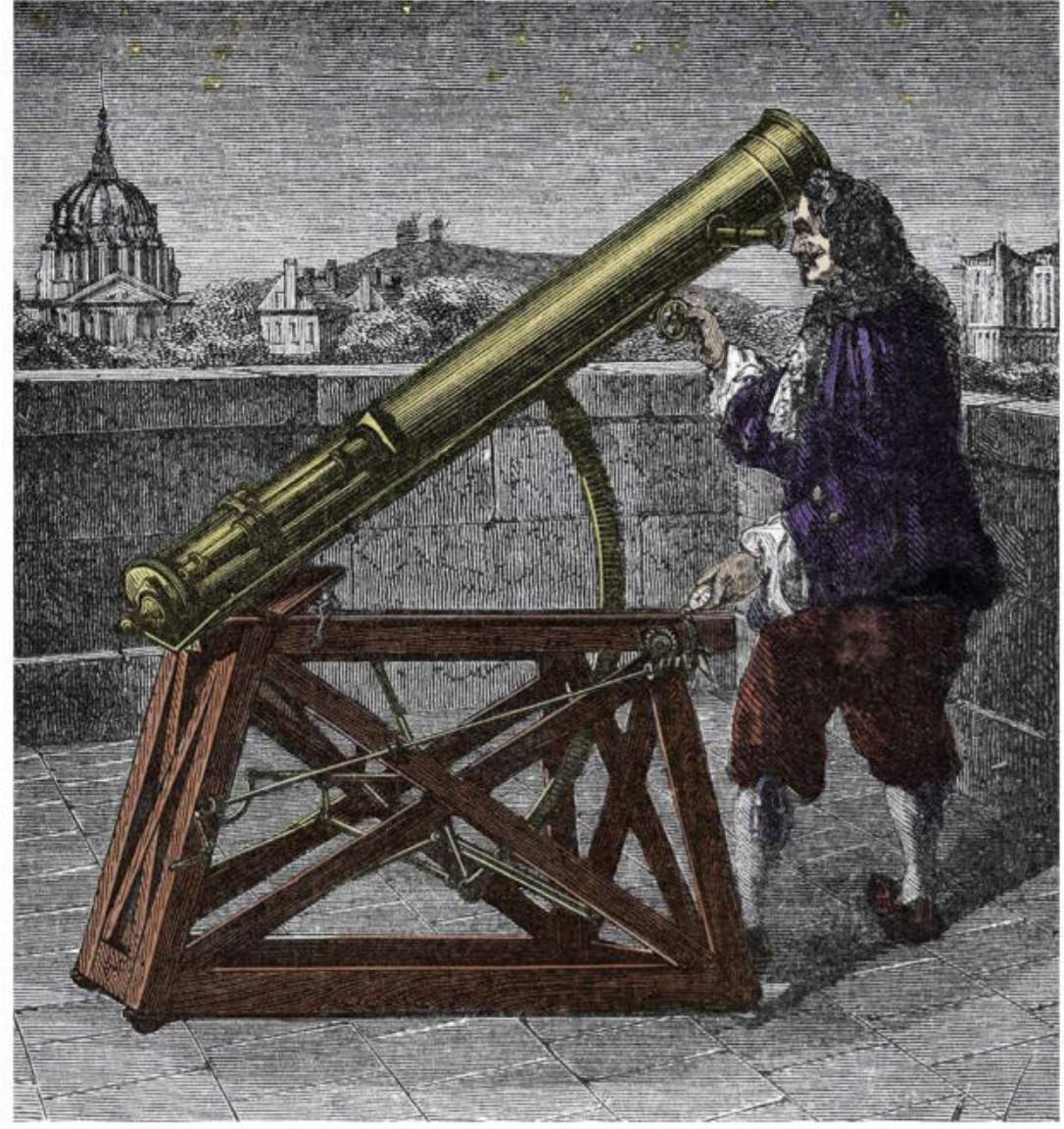
DE TRIGONO IGNEO. 25

masculina. Aries igitur, & cum eo triangulantia, Leo & Sagittarius
sunt ignea. In primo quadrante principium Aries, in secundo me-

dium Leo, in tertio finis Sagittarius. Quartus quadrans hyemalis ca-
ret signo igneo.

Sed cur tria succedentia, Tauruſ, Virgo, Capricornus, terrea potius
quàm aërea, cùm aër immediatè succedat igni? Cauſam refert Albuma-
ſar hanc: Calori quidem actionem eſſe vivificandi: frigori verò itidem
actionem, ſed mortificandi, & corrumpendi: Omnem verò activam
qualitatem paſſivâ eſſe nobiliorem: itaq; Tauro, qui proximè ſequitur
Arietem, activam qualitatem alteram obtigiſſe, frigus nempe, & inter
elementa terram, frigoris ſedem. Itaq; quæ proportio eſt vitæ ad mor-
tem, diei ad noctem, maris ad fœminam; hæc quoque videbatur caloris
ad frigus. Nam & fœmina in generandi actu aliquid agit (invadus

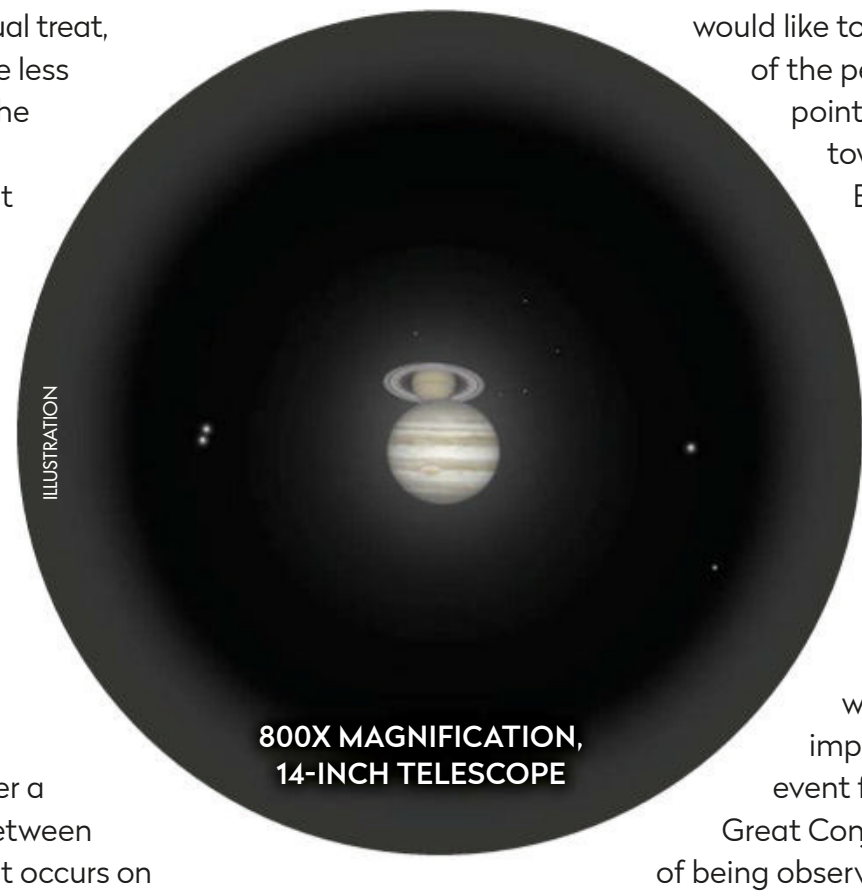


▲ Above: Kepler's trigon, a diagram of Great Conjunctions from 1583–1723 published in his 1606 book *De Stella Nova*

Above, right: a 17th-century Gregorian telescope, of the kind perhaps used to make the first recorded telescopic observation of a Great Conjunction in 1683

This was only a brief visual treat, however, as the Sun rose less than 45 minutes after the planets became visible. This brings us to the last Great Conjunction, which took place on 31 May 2000. Alas, it was unfavourable since both planets had recently been in conjunction with the Sun, rising some 45 minutes before it into pre-dawn skies in Taurus.

After 2020, only one further conjunction up until 2100 will offer under a degree of separation between Jupiter and Saturn. That occurs on 15 March 2080, and will be located – just like this December's – in the constellation of Capricornus. Its elongation west of the Sun will be a nice 44° and the pairing will rise some 25 minutes before the Sun. The planet Uranus will join in the party, lying just a little to the west of the pair. Also like this December's event, the separation between Jupiter and Saturn will be 6 arcseconds, but with this time with Jupiter to the north of Saturn.



▲ No need to wait 5,521 years... this is how the occultation of Saturn by Jupiter in the year 7541 will look at the eyepiece

Through the ages

From our review of 300 years of Great Conjunctions it is plain that this year's is uniquely favourable, which is why we must make every effort to observe it despite it being visible for a short period from the UK. Indeed, the last Great Conjunction that was as visually close as this one was on 16 July 1623. At that time, 397 years ago, the telescope was a fairly new invention, and we would like to think that astronomers of the period were eager to point this new technology towards such a great event.

But a scan through the history books reveals nothing of note. The problem with this conjunction was that on 16 July, Jupiter and Saturn were a mere 13° east of the Sun, so by twilight the pair were very close to the horizon at mid-latitudes and it would have been virtually impossible to observe this event from the UK. The first Great Conjunction to have a record of being observed with a telescope was on 8 February 1683, and with that in mind we can see just how important this December's event is historically – it is the closest ever of the telescopic age.

In the run up to 21 December, as you wait anxiously for a forecast of clear skies to witness part of astronomical history for yourself, you may be wondering whether it is possible for Jupiter to occult Saturn at a Great Conjunction. The simple answer is, yes, but this is an extremely rare phenomenon and will next happen on 10 February 7541. What an apparition that will be, with astronomers of the far future being able to see them rising in darkness, reaching an altitude of over 40° above the southern horizon and visible throughout the night on the Taurus-Orion border.

For more on the Great Conjunction of Jupiter and Saturn turn to our Sky Guide on page 47

Neil Norman has been a planetary observer for over 40 years and is a co-host of the internet radio show, *Anglo-Irish Astro Geeks*. A Fellow of the Royal Astronomical Society, asteroid 314650 is named in his honour

Outer reaches: an artist's impression of New Horizons shows the spacecraft exploring a Kuiper Belt object with the Sun (centre) as a distant bright star

ILLUSTRATION

Looking for a NEW HORIZON

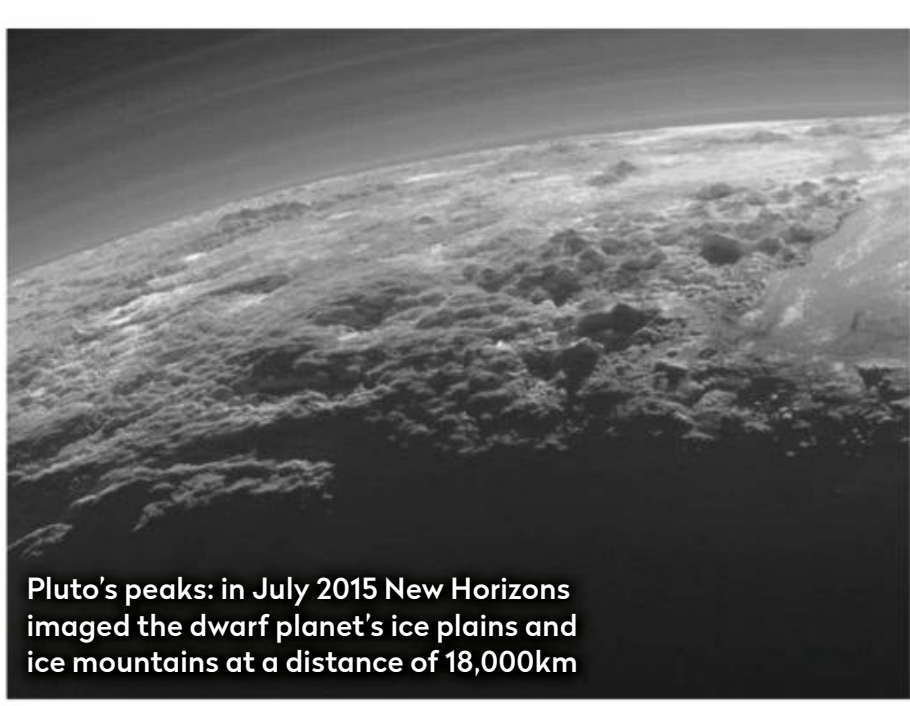
As the New Horizons spacecraft sails through the Kuiper Belt, **Will Gater** investigates how the mission is continuing to study objects it can spy from afar

There's a good chance that as you read these words, almost seven lighthours from Earth an explorer is opening its eyes to the tenebrous emptiness of deep space. That explorer is the New Horizons spacecraft, currently sailing through the outer Solar System at 50,000km/h. This December it will spend several days turning one of its cameras towards some of the small, icy bodies that live in the deep recesses of this isolated realm.

While the pictures returned by this new set of observations will be little more than dots against a starry backdrop, they could help researchers plumb the deep history of our planetary neighbourhood.

When it launched in 2006, New Horizons' primary target was the Pluto system. The one-time planet and its moons lie some 5.75 billion km from Earth, within a zone of our planetary neighbourhood that astronomers call the Kuiper Belt. Here, beyond the orbit of the gas giant Neptune, lie not only Pluto and several other frozen worlds over 1,100km in diameter, but thousands of smaller, icy objects.

New Horizons' exploration of Pluto was humanity's first foray into this enigmatic region, and as the spacecraft flew past the dwarf planet's frosted globe in 2015, it captured enthralling views of obliquely lit ice mountains and immense, frozen plains peppered with craters (see picture, right). But the team controlling the spacecraft also had their eyes on what lay in the shadows beyond.



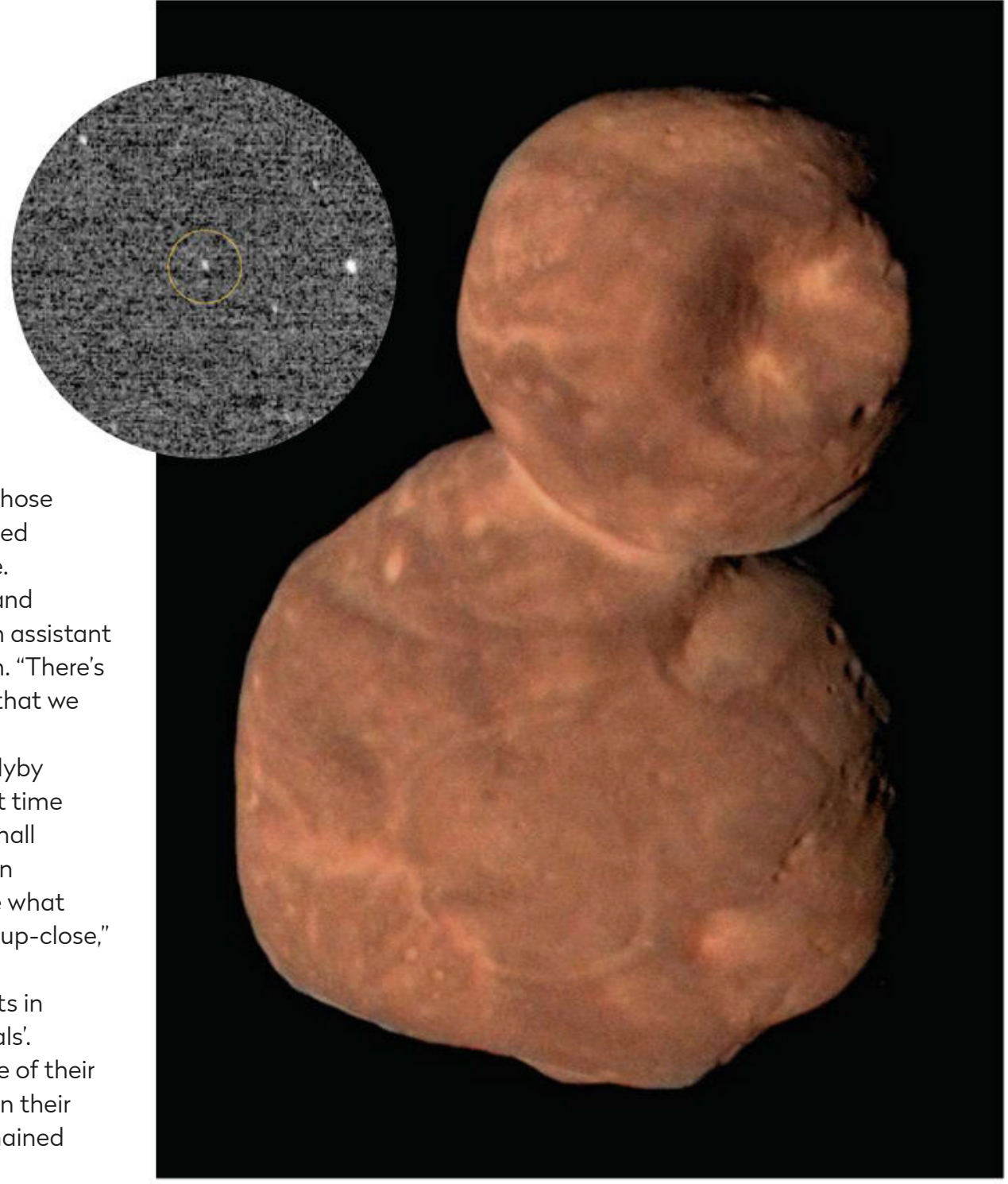
Pluto's peaks: in July 2015 New Horizons imaged the dwarf planet's ice plains and ice mountains at a distance of 18,000km

NASA/ESA/AND G. BACON (STSCI), NASA/JOHNS HOPKINS UNIVERSITY APPLIED PHYSICS LABORATORY/SOUTHWEST RESEARCH INSTITUTE

Following a detailed search in 2014, astronomers had discovered a Kuiper Belt inhabitant more than 1.3 billion km beyond Pluto, which was in a position where the perpetually outbound probe could pay it a fleeting flyby.

Deep-space discovery

So it was that, as bleary-eyed revellers welcomed in the first few hours of 2019, New Horizons was beaming home images and scientific measurements of 'Arrokoth' – a strange, roughly 30km-long, object seemingly made of two icy bodies that have collided and become one. It's been the examination and ▸



▲ Rock of ages: by analysing New Horizons flyby images of Arrokoth, scientists discovered that its two lobes experienced the same evolution over the lifespan of the Solar System; (inset) an image captured by New Horizons' long range camera (LORRI) shows the object when it was 10 million km from the spacecraft

NASA/JOHNS HOPKINS UNIVERSITY APPLIED PHYSICS LABORATORY/ SOUTHWEST RESEARCH INSTITUTE X 2, MOPIC / ALAMY STOCK PHOTO

▸ interpretation of the results collected in those precious hours at Arrokoth that has occupied many of the scientists on the mission since.

"It's been a whirlwind of data reduction and analysis," says Professor Anne Verbiscer, an assistant project scientist on the New Horizons team. "There's just a tremendous amount of information that we learned from that flyby."

Part of the significance of the Arrokoth flyby observations is that they represent the first time that researchers have seen one of these small and extremely distant Kuiper Belt objects in such detail. "It's really been amazing to see what something that far from the Sun looks like up-close," says Verbiscer.

Arrokoth is part of a population of objects in the Kuiper Belt known as the 'Cold Classicals'. Although these are frozen entities, by virtue of their immense distance from our star, the 'cold' in their name actually refers to how they have remained unperturbed over the eons.

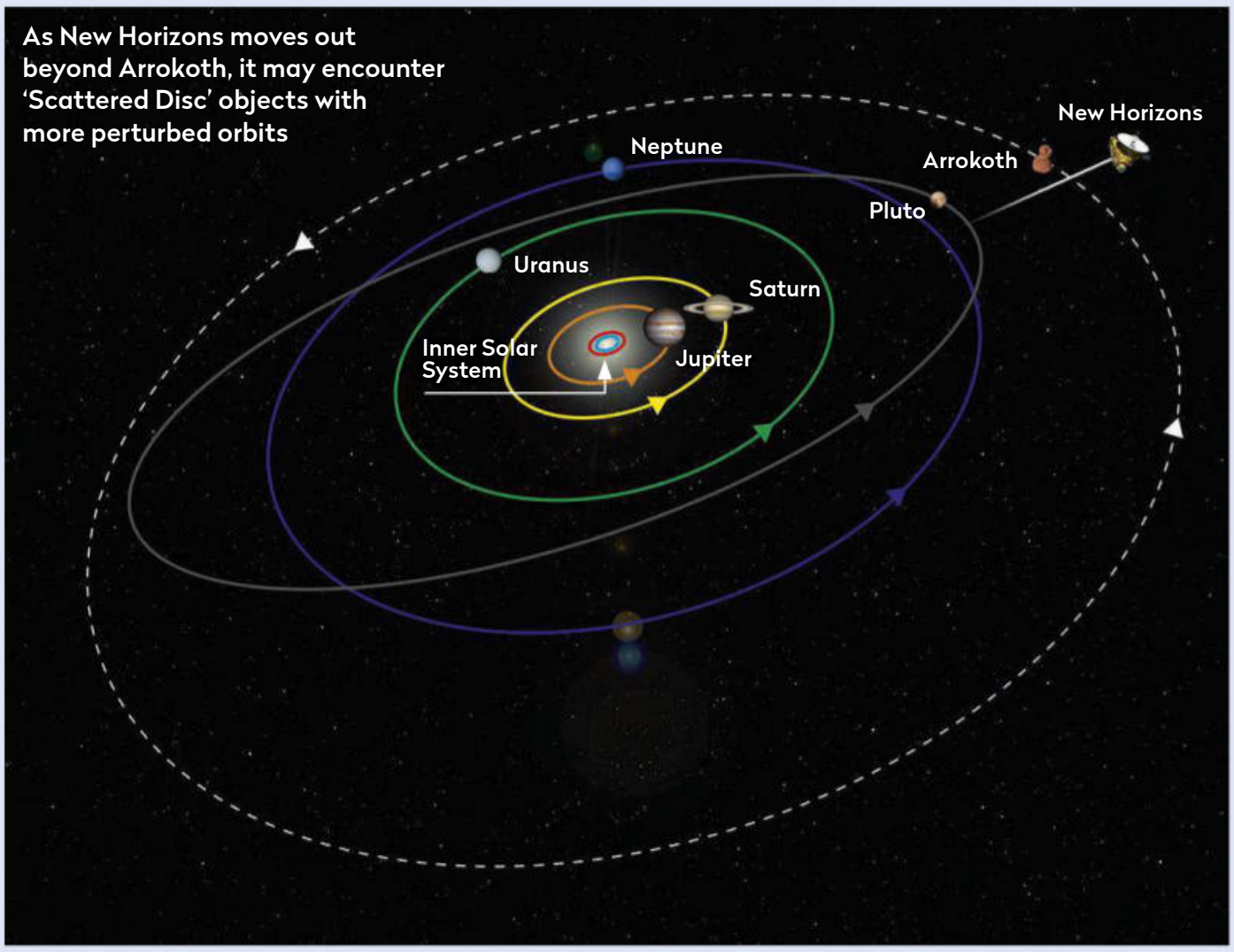
"Their positions, or their orbits, have not been altered in any way," explains Verbiscer. "They've been travelling around the Sun for four billion years and they haven't budged. So they are located where they

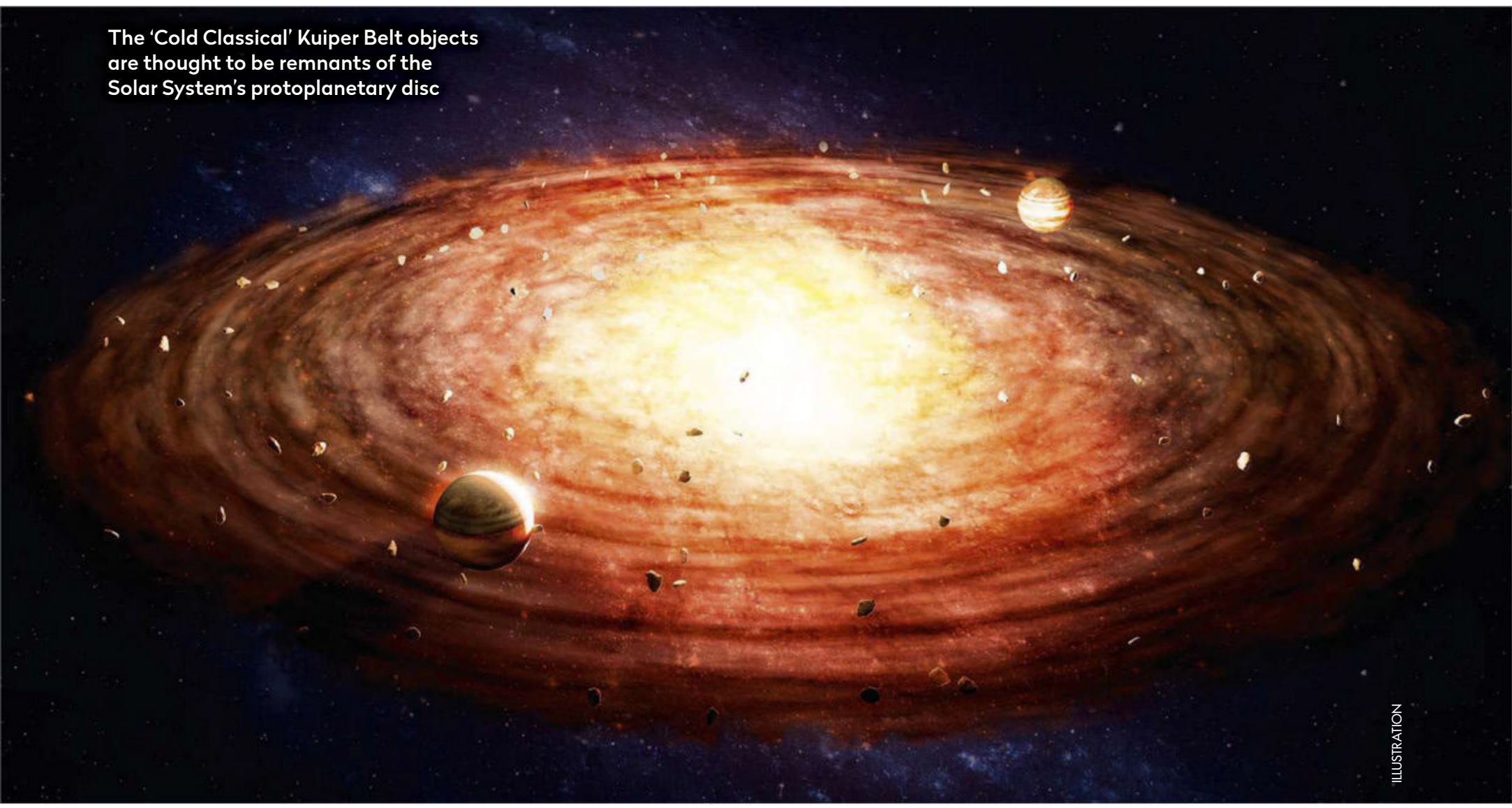
Sailing through the Kuiper Belt

New Horizons is speeding away from the Solar System

The New Horizons spacecraft is currently far beyond the orbit of Pluto and indeed already well past the orbit of the Kuiper Belt object Arrokoth, which it visited in late 2018 and early 2019. By the middle of this month it will be some 7.4 billion km from Earth.

You can keep track of New Horizons and the four other spacecraft speeding away from our Solar System yourself using the NASA Eyes app at **https://eyes.nasa.gov/**





The 'Cold Classical' Kuiper Belt objects are thought to be remnants of the Solar System's protoplanetary disc

ILLUSTRATION

"This is our first close look at something that is considered to be a building block for the Solar System." – Professor Anne Verbiscer

were formed and haven't been changed by any kind of migration or influence by the outer planets, most notably Neptune."

Indeed, it's thought that the Cold Classical Kuiper Belt objects are the primordial remnants of the protoplanetary disc, out of which the planets we know today emerged. "This is our first close look at something that is considered to be a building block for the Solar System," says Verbiscer.

Clues about the Solar System

All of this means that the scientific data from the Arrokoth flyby is rich with clues as to how some of the most ancient Kuiper Belt objects – and, by extension, the larger worlds within our planetary family – were constructed. For example, the images from New Horizons show that the two parts of Arrokoth share the same composition, the same colour and the same level of scarring by meteoroid impacts. That tells scientists a lot about the history of this pair of now joined objects. "The similarity of Arrokoth's lobes suggests that they were formed in the same place, from the same material, and that they have experienced the same evolution over the age of the Solar System," explains Verbiscer.

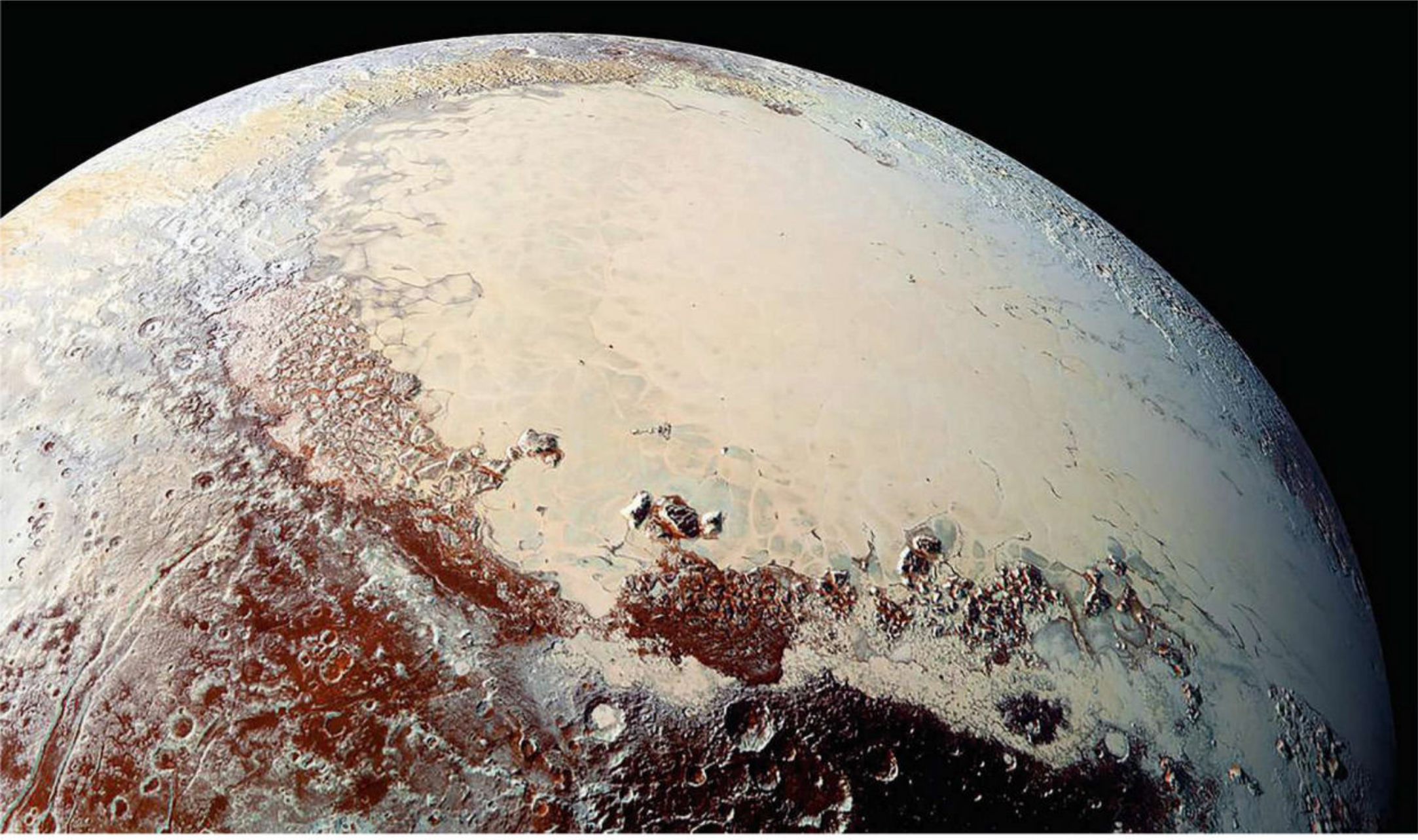
When New Horizons makes its December observations, it'll be enhancing astronomers' picture of the Kuiper Belt, providing context for the data collected at Arrokoth and the other studies of Kuiper Belt objects it's made during its mission.

"We're starting to look at enough of them – and get enough of a statistical sample – to make conclusions about one class of objects versus another," says Verbiscer. What's more, some of the December targets may be part of a collection of bodies whose story is very different to the Cold Classical Kuiper Belt objects.

These are objects whose orbits – unlike those of Arrokoth and its kin – were very much perturbed in the early period of the Solar System's life. They are thought to have been ejected outwards by gravitational interactions with the gas giants, and now reside in what's known as the 'Scattered Disc' region of the Kuiper Belt.

"They're going to be inclined to the ecliptic, or the plane that all the planets and the Cold Classical Belt orbits in," explains Verbiscer. "We're definitely looking forward to seeing these scattered objects because we haven't looked at too many of those so far at all."

New Horizons' quarries for its new run of observations this December were found earlier this year, not by the spacecraft's instruments, but by a ground-based survey involving researchers from Canada, Japan and the New Horizons team itself. "They were all discovered using the Japanese Subaru telescope in Hawaii, specifically with its Hyper SuPrime Camera, which has a huge field of view," says Dr Simon Porter, a co-investigator working on the ▸



▸ mission. In total some 90 Kuiper Belt objects were uncovered by this detailed search, but only nine appear to be within the observing capabilities of the NASA craft.

Even now, at the time of writing, just a couple of months from when the observations will happen, the team are racing to gather more information about the shortlist. "The biggest challenge right now is fighting the clock," says Porter. "New Horizons is rapidly moving away from the centre of the Kuiper Belt, so the number of Kuiper Belt objects near the spacecraft is declining over time. That means that most of the objects that we found are visible sooner rather than later, and we need to work quickly to determine their orbits well enough to observe them with New Horizons."

To achieve this, Porter and his colleagues intend to bring the powerful optics of the Hubble Space Telescope to bear upon the nine distant bodies. "We can then use the high-precision Hubble data to either guide the New Horizons observations of these objects in December, or rule them out as too faint [for the probe to see]," he adds.

Going the distance

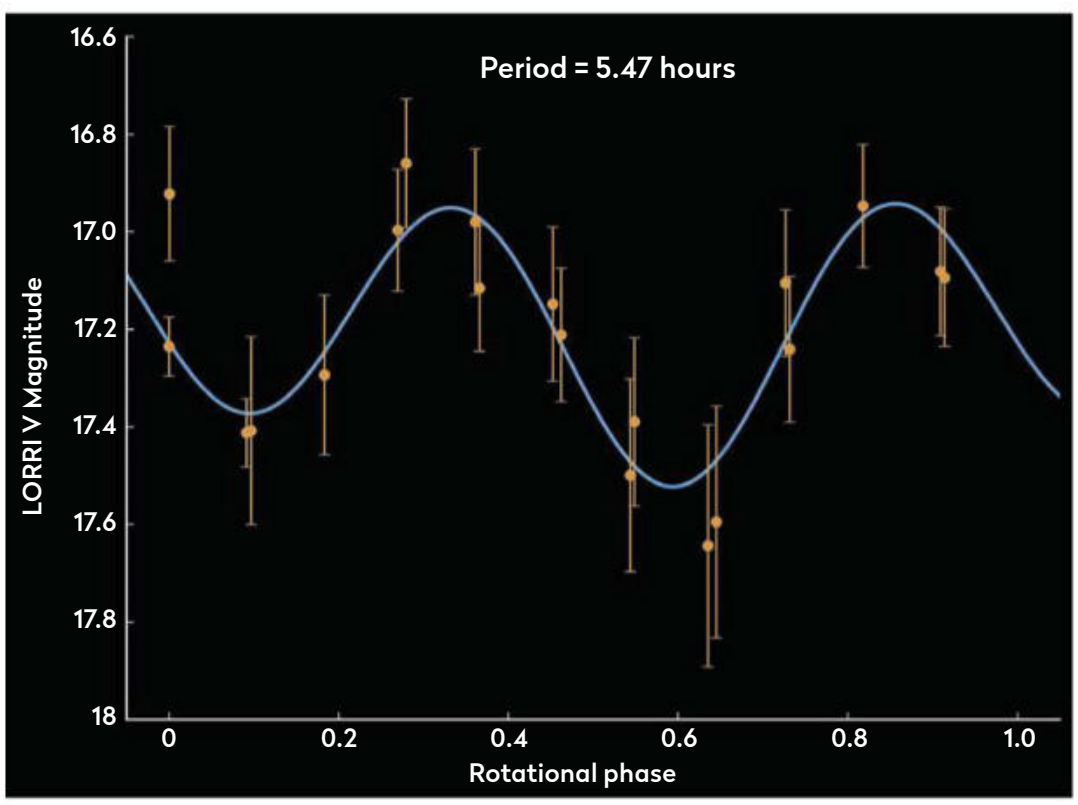
Due to the great distance that New Horizons will be observing the targets at – the spacecraft flew about 3,500km from Arrokoth, but these will be some 150 million km off, and potentially further – it'll be the probe's sensitive long-range camera, LORRI, that will be making the December observations. Even then, though, the icy objects will only appear as a fleck of light against the background stars. That tiny spot contains a great deal more information than you or I might think, however.

Among the things that the data can allow scientists to examine is how the Kuiper Belt object scatters light. One currently unresolved mystery is that the larger worlds of the Kuiper Belt – like Pluto, MakeMake, Eris and Haumea – seem to scatter light differently to the smaller bodies, such as Arrokoth. Could this be down to a difference in surface texture or is it something to do with the shape of the objects?

"My suspicion is that it's a combination of both," says Anne Verbiscer. "The question would be, can we disentangle those two things and say this much is attributed to an irregular shape and this much of what we see is because the surface is actually something different." Gathering more observations may help illuminate the answer.

For some of the brighter Kuiper Belt objects it'll be studying, New Horizons will be making repeat observations over the course of 18 hours.

▲ Why does a large Kuiper Belt object (KBO) such as Pluto scatter light differently to a smaller one?

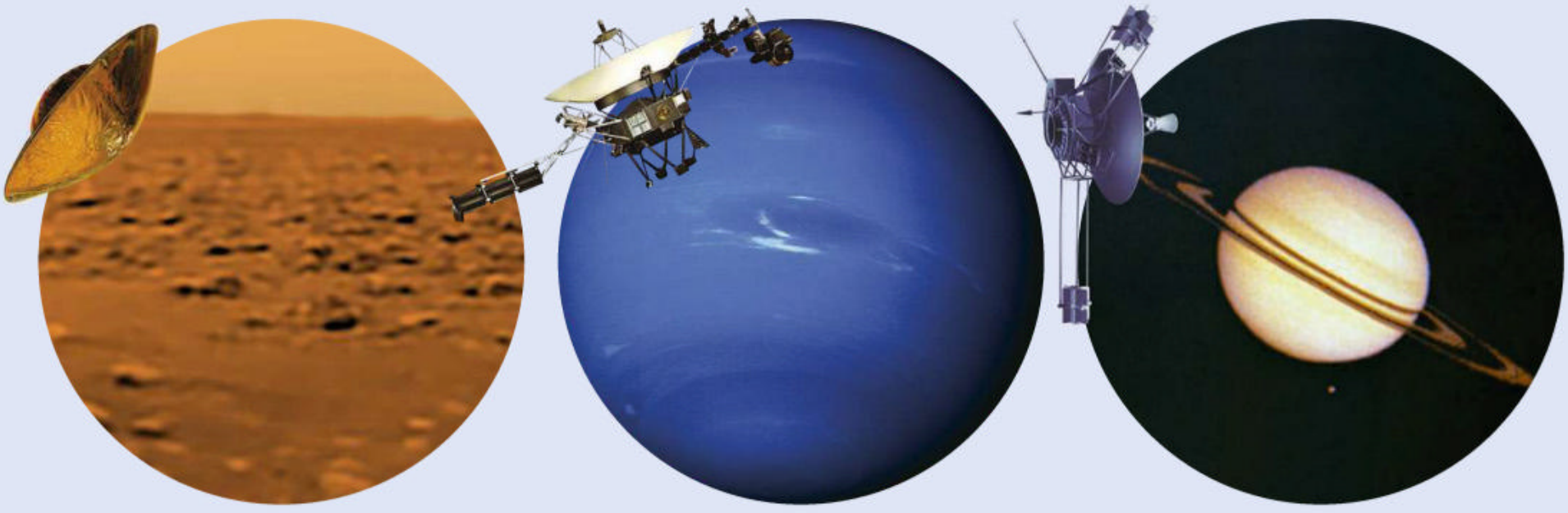


▼ An example of light-curve data taken by New Horizons of a KBO called JR1 – unlike Earth-based telescopes, New Horizons can view a KBO from the side

NASA/JOHNS HOPKINS UNIVERSITY APPLIED PHYSICS LABORATORY/SOUTHWEST RESEARCH INSTITUTE, NASA/JHUAPL/SWRI, ESA/NASA/JPL/UNIVERSITY OF ARIZONA, NASA/JPL, NASA AMES

Messages from afar

New Horizons was the first spacecraft to give us incredible up-close views of worlds in the Kuiper Belt, but it's not the only mission to return data from distant realms



Huygens

The European Space Agency's Huygens probe was sent to Saturn's moon Titan in 1997. It travelled on-board NASA's Cassini spacecraft, and in 2005, after a parachute descent through haze-laden skies, landed on Titan, capturing never-before-seen views from its sub-zero surface. With Saturn's average distance from Earth being 1.3 billion km, the pictures and scientific data Huygens sent home are still the furthest messages we've received from the terra firma of another world.

Voyager 1 & 2

NASA's two Voyager spacecraft performed spectacular tours of the outer planets in the 1970s and 1980s. The pictures Voyager 2 beamed back during flybys of distant Uranus and Neptune are the only close-up impressions we've had of these worlds and their intriguing array of moons. Both Voyager 1 and 2 have remained in contact with Earth, as they slip further from the Sun; some scientists believe that data returned in recent years indicates the probes have entered 'interstellar' space.

Pioneer 10 & 11

The Pioneer 10 spacecraft lifted off from Cape Canaveral, Florida, in 1972. It was followed by Pioneer 11 in 1973. The target for the former was Jupiter while the latter travelled to Jupiter and Saturn. The missions would be humanity's first exploration of the outer planets. Both spacecraft were sent on flyby-style trajectories, and they remain outward bound from our star to this day. Communication was lost with Pioneer 11 in 1995 while Pioneer 10 went silent in 2003.

Will Gater is an astronomy journalist and science presenter. His latest book, *The Mysteries of the Universe*, has recently been published by DK

By examining how the brightness of the targets fluctuates, researchers on the mission will be able to create so-called 'light-curves' for the bodies.

"What you'd like to see then is a repeated pattern of getting bright, getting dark, getting bright, getting dark," explains Verbiscer, describing the changing pattern of brightness as the target spins. "You can match that up [and] fold it on to itself, and that's how you get the rotation period," she adds.

The light-curves acquired from the unique perspective of New Horizons could also be analysed alongside those created from ground-based studies, potentially revealing insights into the shape of some of these distant Kuiper Belt objects.

"When you're looking from the vantage point that New Horizons has out in the outer Solar System, compared with the viewing geometry you would have here from Earth [based observations], those light-curves look quite different from objects that have irregular shapes," says Verbiscer.

Incredibly, the light-curve and light-scattering measurements can even give clues to the nature of the target's surface. For example, one property the team may be able to examine is the porosity of the material on the object – that is how 'fluffy' the ground is. "We think that micrometeoroids bombarding the surface is what makes it fluffy," says Verbiscer. "So that would be a measure of how much bombardment it's experienced over its entire lifetime."

Against the backdrop of the mission's observations this month, there's still something of a lingering hope that New Horizons might be able to make another close – Arrokoth-style – visit to a Kuiper Belt object that is further out. Both Porter and Verbiscer stress that the odds of finding a suitable destination appear to be slim, though. "We're checking every object to make absolutely sure," says Porter. "Like for Arrokoth, the Hubble observations are critical for knowing the orbits of the [objects] well enough to know if they are potential flyby targets." For a mission that's produced so many surprises so far, such a finding would certainly rank as one of its most welcome.

The fundamentals of astronomy for beginners

EXPLAINER

Mary Somerville

The pioneering science writer and first woman member of the Royal Astronomical Society

Mary Somerville was remembered as the 'queen of science'

JOSEPH GAUL/ALAMY STOCK PHOTO, NASA/LRO

Mary Somerville was a celebrated lady of science of her day. Her name lives on in the Oxford College named after her, there's a crater on the Moon that bears her name and in 2017 her face featured on the Scottish £10 note, but who was she, and why is she so celebrated?

Like many women within the history of science, her story is complicated. While their male peers were allowed to join and be educated within prestigious institutions, publish original work under their own name and be declared discoverer, inventor and theorist, women did not have those options. Instead, women often had to rely on generous friends and relatives to educate them and speak up for their achievements. They had to hide their originality too, disguising it behind respectable female accomplishments such as translation or teaching, which is how it was for Mary Somerville (née Fairfax).

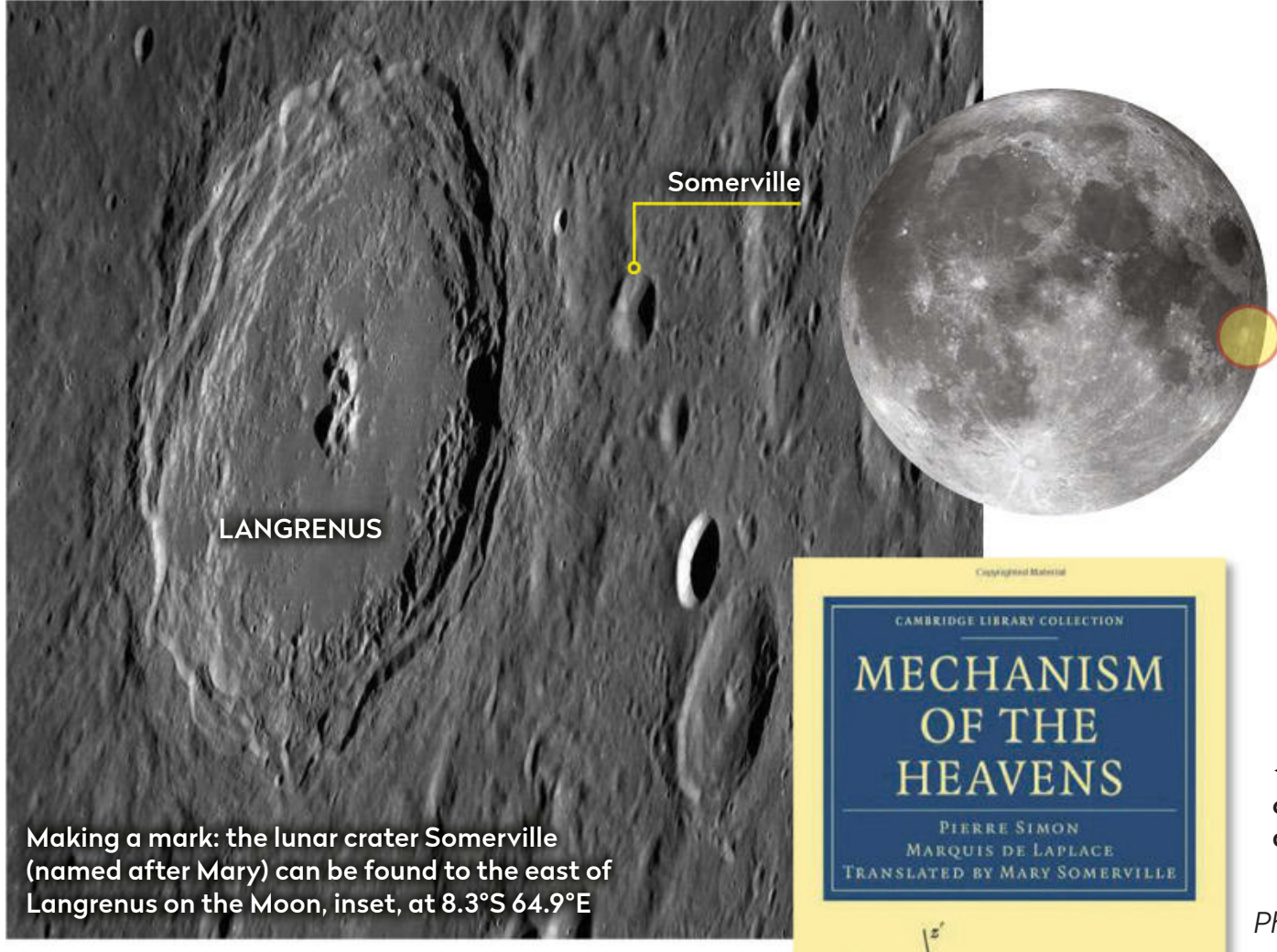
▲ **Noteworthy: in 2017 the Royal Bank of Scotland began featuring Mary Somerville's portrait on £10 notes**

Early promise

Mary Somerville was born in Scotland at the home of her uncle Dr Thomas Somerville on Boxing Day 1780. Her family were upper middle class (her father was a Vice-Admiral) and comfortable if not wealthy. At 10 years old Mary was sent away to the first of many schools, a boarding school which taught her English and French; she also spent time at a village school, a writing school in Edinburgh, a dance school and Nasmyth's Academy. Back home she collected shells (later donated to Somerville College) and devoured books, a pastime some of her family disapproved of, regarding it as unfeminine to read so much. While some looked down their noses, her uncle, Dr Somerville was encouraging, introducing her to men of science and providing access to his own scientific and philosophical library. Mary was also strongly political – as a child she gave up sugar in protest against slavery and she later became a keen advocate of women's education and suffrage.

In 1804 she met her first husband, Captain Samuel Greig. He was opposed to female learning and although he allowed her to pursue her interests he also discouraged her. When he died in 1807, he left her with two young children and an inheritance sufficient to allow her to study in earnest. She threw herself into these studies and when confident began testing out her understanding by sending in solutions to mathematical puzzles (under the pseudonym "A lady") to the *Mathematical Repository*.

In 1812 she married her cousin Dr William Somerville, who like his father (and unlike her first husband)



Making a mark: the lunar crater Somerville (named after Mary) can be found to the east of Langrenus on the Moon, inset, at 8.3°S 64.9°E

supported and encouraged Mary's pursuit of scientific and intellectual knowledge. They moved to London and there mixed with many great figures from science and the arts. In 1826, at the age of 46, she published her first scientific paper on magnetism and the solar spectrum. Not long after she was asked to translate Pierre-Simon Laplace's *Traité de mécanique céleste* for the Society for the Diffusion of Useful Knowledge, a publishing project designed to give access to new ideas to the working and middle classes and tempt them away from radical politics. The resulting book, *Mechanism of the Heavens* (1831) was not just a translation but a clarification of the ideas it contained. It made her and became a textbook for Cambridge undergraduates until the 1880s. If looking for her impact on the world of astronomy, this would be it: her books helped shape the education and ways of thinking of several generations.

Best-sellers

While her first book had been successful and well received, it was her second, *On the Connexion of the Physical Sciences* (1834) that cemented her reputation and became one of the best-selling science books of the 19th century. In his anonymous review William Whewell noted that, given the ever developing and expanding nature of scientific enquiry, a new term was required for its practitioners, suggesting in his review the word 'scientist', which he coined in analogy with 'artist'. There followed awards and honorary memberships from societies around the world, including the Royal Astronomical Society, which broke with tradition to make Mary Somerville and Caroline Herschel their joint first female honorary members in 1835.

From around the time of her second book, until her death in 1872, Mary and her husband lived mainly in Italy. There, she published two more books. Her two surviving daughters went with them, caring for their mother in her old age. In 1874 her collected letters were published (around the same time as Caroline Herschel's). Her obituary in *The Morning Post* declared Mary Somerville to be 'the queen of science'.

◄ **Inspirational: the *Mechanism of the Heavens* was acclaimed by astronomers and mathematicians**

Dr Emily Winterburn is author of *The Quiet Revolution of Caroline Herschel: The Lost Heroine of Astronomy*

A literary legacy

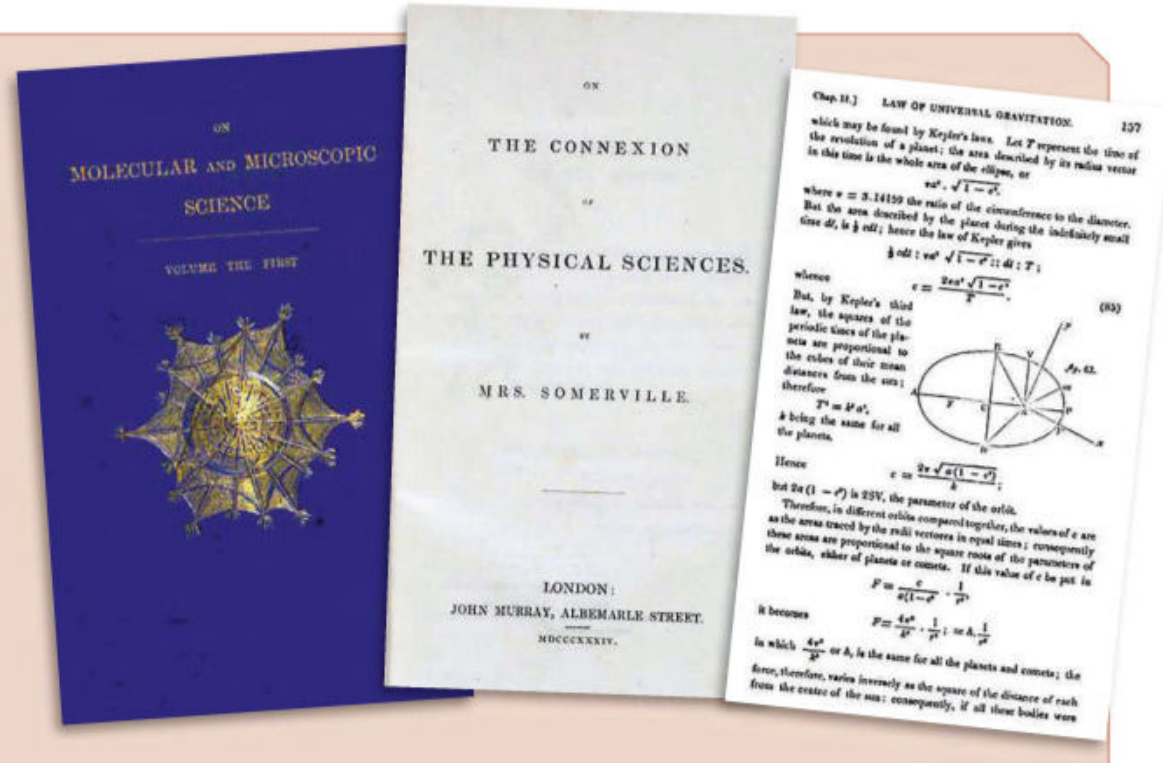
Mary Somerville's published works became scientific best-sellers during the Victorian era

Her first book, ***Mechanism of the Heavens*** (1831), was used as a textbook to teach University of Cambridge undergraduates.

On the Connexion of the Physical Sciences (1834), her second book, became one of the best-selling science textbooks of the 19th-century before Charles Darwin.

Her next book, ***Physical Geography*** (1848), was the first English textbook on its subject-matter. It was used in universities for decades.

The fourth, ***Molecular and Microscopic Science*** (1869), was a commercial success, but regretted by Mary who wished she had spent more time on her true passion: mathematics.



▲ **Original pages and covers from some of Mary Somerville's books; far right, a page from her first, a translation of *Mechanism of the Heavens***

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The Sky Guide

DECEMBER 2020

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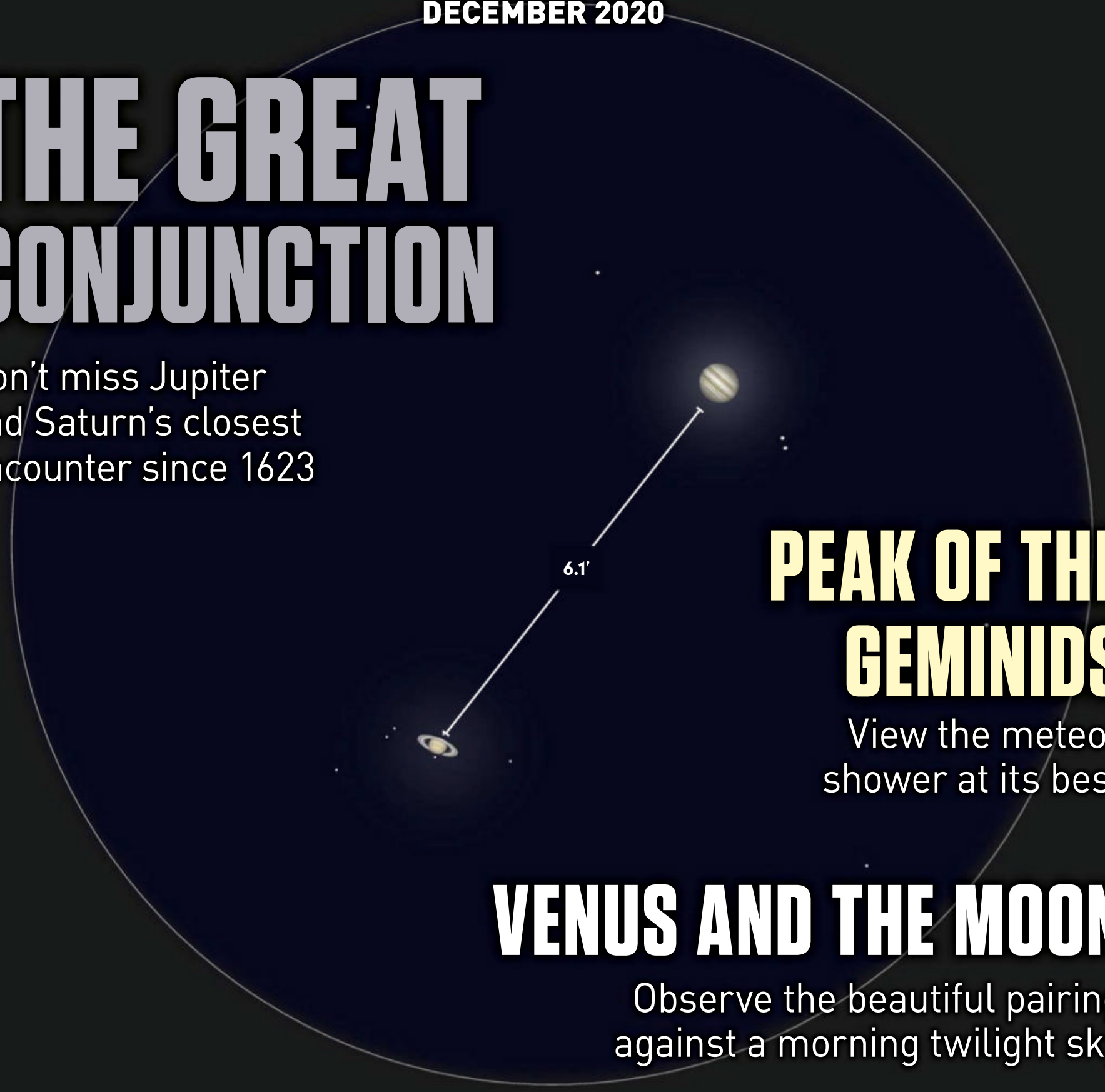


PETE LAWRENCE

PEAK OF THE GEMINIDS

View the meteor shower at its best

VENUS AND THE MOON

Observe the beautiful pairing against a morning twilight sky

About the writers

Astronomy expert **Pete Lawrence** is a skilled astro imager and a presenter on *The Sky at Night* monthly on BBC Four

Steve Tonkin is a binocular observer. Find his tour of the best sights for both eyes on page 54

Also on view this month...

- ✦ Minor planet 13 Egeria reaches opposition
- ✦ Get to know the lunar feature Mare Vaporum
- ✦ Zoom in on the tip of Taurus's northern horn

Red light friendly

To preserve your night vision, this Sky Guide can be read using a red light under dark skies

Get the Sky Guide weekly

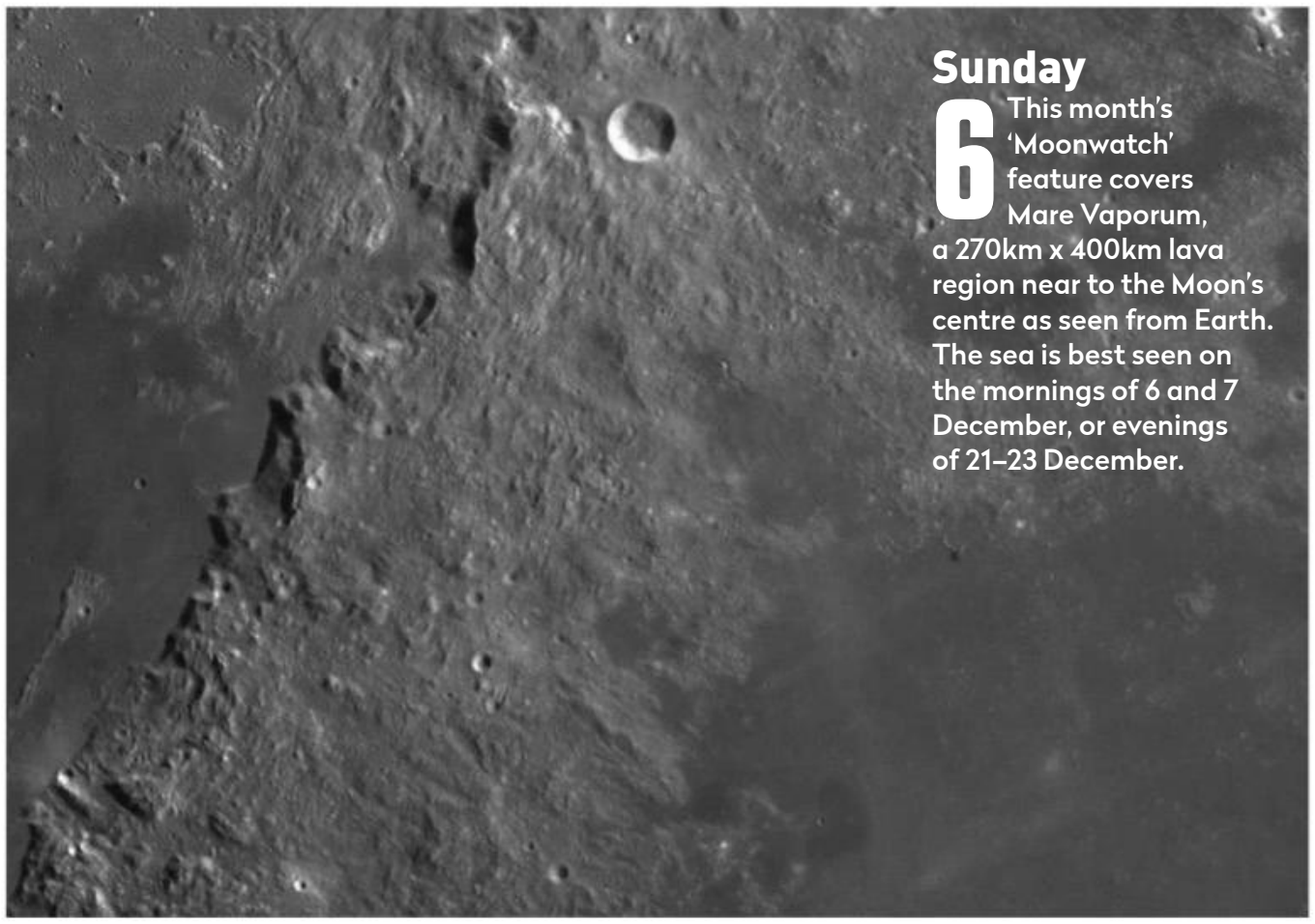
For weekly updates on what to look out for in the night sky and more, sign up to our newsletter at **www.skyatnightmagazine.com**

DECEMBER HIGHLIGHTS

Your guide to the night sky this month

Saturday 5

This morning around 01:00 UT a 79%-lit waning gibbous Moon lies 1.9° to the north of M44. The Moon will drown out the cluster for naked-eye viewing, but binoculars should reveal its presence.



Sunday 6

This month's 'Moonwatch' feature covers Mare Vaporum, a 270km x 400km lava region near to the Moon's centre as seen from Earth. The sea is best seen on the mornings of 6 and 7 December, or evenings of 21–23 December.

Sunday 13

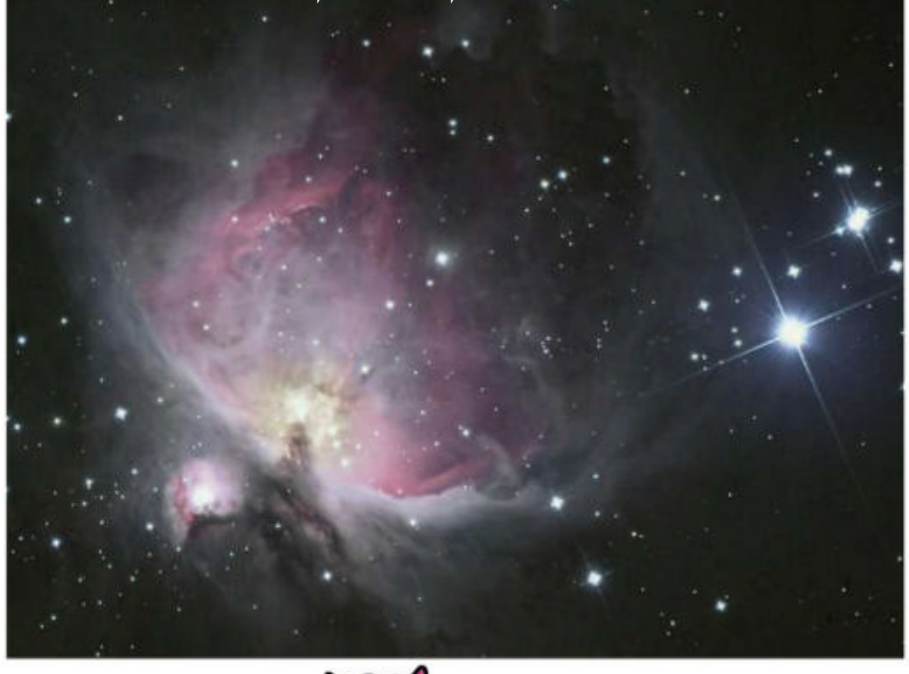
This morning's view of Venus and the Moon has bright Venus appearing above and right of a very thin 2%-lit waning crescent Moon from around 07:15 UT. Look for them low above the southeast horizon.

Thursday 17

Look southwest at 17:00 UT this evening to see the fine sight of mag. –1.8 Jupiter 28 arcminutes from mag. +0.9 Saturn. An 11%-lit waxing crescent Moon sits 7° to the left of the pair as seen from the UK. The planets set around 18:30 UT.

Friday 18

The majestic winter constellation of Orion is centre-stage at midnight UT. Orion contains many iconic features of the night sky including the red supergiant Betelgeuse, the blue supergiant Rigel, the Belt of Orion and, of course, the famous Orion Nebula.



Sunday 20

Minor planet 13 Egeria is at opposition in Auriga, shining at mag. +10.0.

Jupiter and Saturn are 9.1 arcminutes apart, low in the southwest, from 40 minutes after sunset.

Tuesday 22

The peak of the Ursid meteor shower occurs today. Recommended observing periods are the early morning of 22 December as well as the following evening.
See page 47 for more.

Wednesday ▶ 23

Tonight, seek out crater Clavius at 23:45 UT to see the Eyes of Clavius clair-obscur effect.

At 19:30 UT Mars is due south and highest for the evening, above a 57%-lit waxing gibbous Moon.

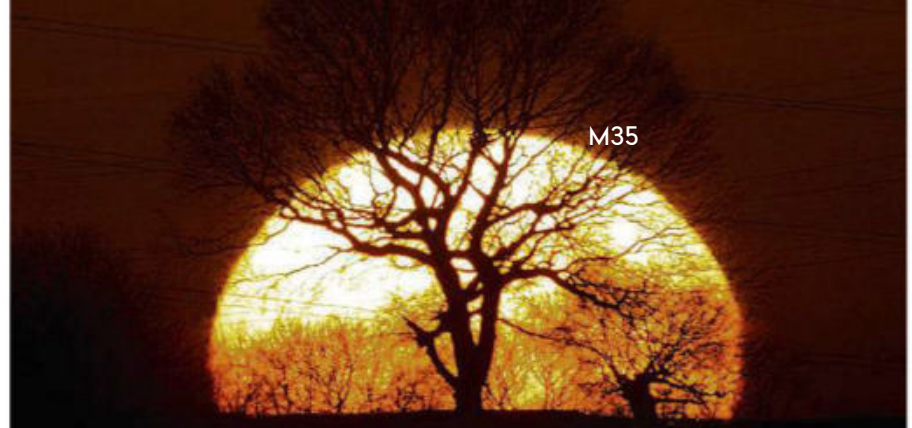
Family stargazing

On 21 December Jupiter and Saturn will be so close to one another in the sky that it'll be hard to tell them apart; indeed at first glance they'll appear as a single bright object – a Christmas Star! Both are visible early evening as the sky begins to darken. In the weeks before the 21st, the planets appear to close in on one another, before beginning to separate again in the evenings after. Get your youngsters to estimate how far they appear separated, using hands and fingers held at arm's length. Repeat over the month, recording the observation to see just how quickly they move. **www.bbc.co.uk/cbeebies/shows/stargazing**

PETE LAWRENCE X 7

◀ Tuesday 29

The famous eclipsing binary star Algol (Beta (β) Persei) is at minimum brightness at 02:50 UT. Algol dips from mag. +2.1 to +3.4 every 2.86 days, due to its dimmer star eclipsing the brighter. Each eclipse minima lasts 9.6 hours.

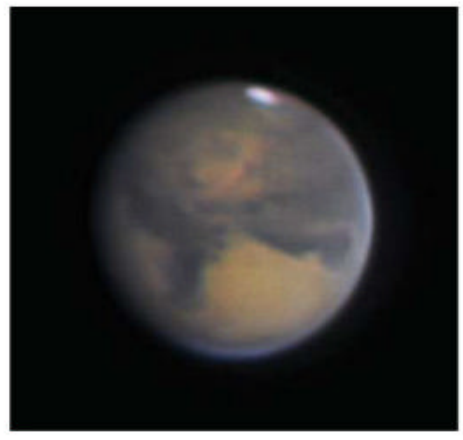


Friday
11 Comet 141P/Machholz is passing through Aquarius. Estimated at mag. +8.8 at midnight on 11 December, the comet is easy to locate, 15 arcminutes west of mag. +3.8 Epsilon (ε) Aquarii.

Saturday
12 **Early risers will get a lovely view of mag. –3.8 Venus, 7.5˚ east-southeast of a 7%-lit waning crescent Moon. At 07:00 UT, both objects are above the southeast horizon against a brightening morning twilight sky.**

Earliest sunset of the year occurs today.

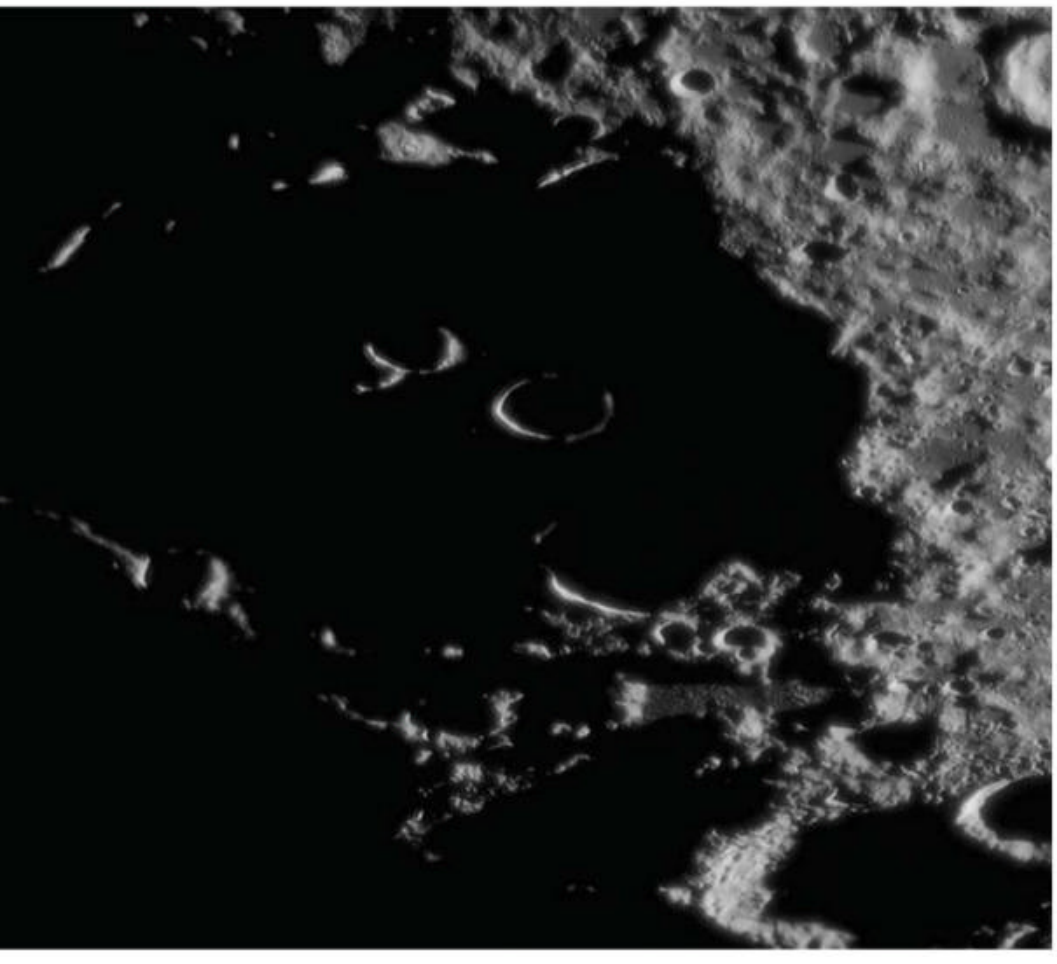
Monday
14 The Geminid meteor shower is set to reach maximum at 00:50 UT, and with today being the date of the new Moon, given clear skies this should be a spectacular display.



◀ Tuesday
15 A telescopic (south-up) view of Mars at 22:00 UT will show the iconic V-shaped albedo feature known as Syrtis Major centred on the disc. To the south is the large circular Hellas Basin with the south polar cap (SPC) near to the southern limb.

◀ Monday
21 The Great Conjunction of Jupiter and Saturn is upon us: they appear a historic 6 arminutes apart at twilight, over in the southwest from around 40 minutes after sunset. See page 47 for more.

The winter solstice is at 13:30 UT.



Thursday
24 This evening the Jewelled Handle clair-obscur effect is visible. It's an illuminated arc of the Jura mountains along the edge of the Sinus Iridum, extending into lunar night. Look out for the effect from 19:30 UT.

Thursday
31 Another opportunity to spot a well-timed eclipse of the Algol eclipsing binary system occurs this evening at 22:10 UT.

NEED TO KNOW

The terms and symbols used in The Sky Guide

Universal time (UT) and British Summer Time (BST)
Universal Time (UT) is the standard time used by astronomers around the world. British Summer Time (BST) is one hour ahead of UT

RA (Right ascension) and dec. (declination)
These coordinates are the night sky's equivalent of longitude and latitude, describing where an object is on the celestial 'globe'

Family friendly
Objects marked with this icon are perfect for showing to children

Naked eye
Allow 20 minutes for your eyes to become dark-adapted

Photo opp
Use a CCD, planetary camera or standard DSLR

Binoculars
10x50 recommended

Small/ medium scope
Reflector/SCT under 6 inches, refractor under 4 inches

Large scope
Reflector/SCT over 6 inches, refractor over 4 inches

GETTING STARTED IN ASTRONOMY
If you're new to astronomy, you'll find two essential reads on our website. Visit **http://bit.ly/10_easylessons** for our 10-step guide to getting started and **http://bit.ly/buy_scope** for advice on choosing a scope

THE BIG THREE

The three top sights to observe or image this month

DON'T MISS

GEMINIDS 2020

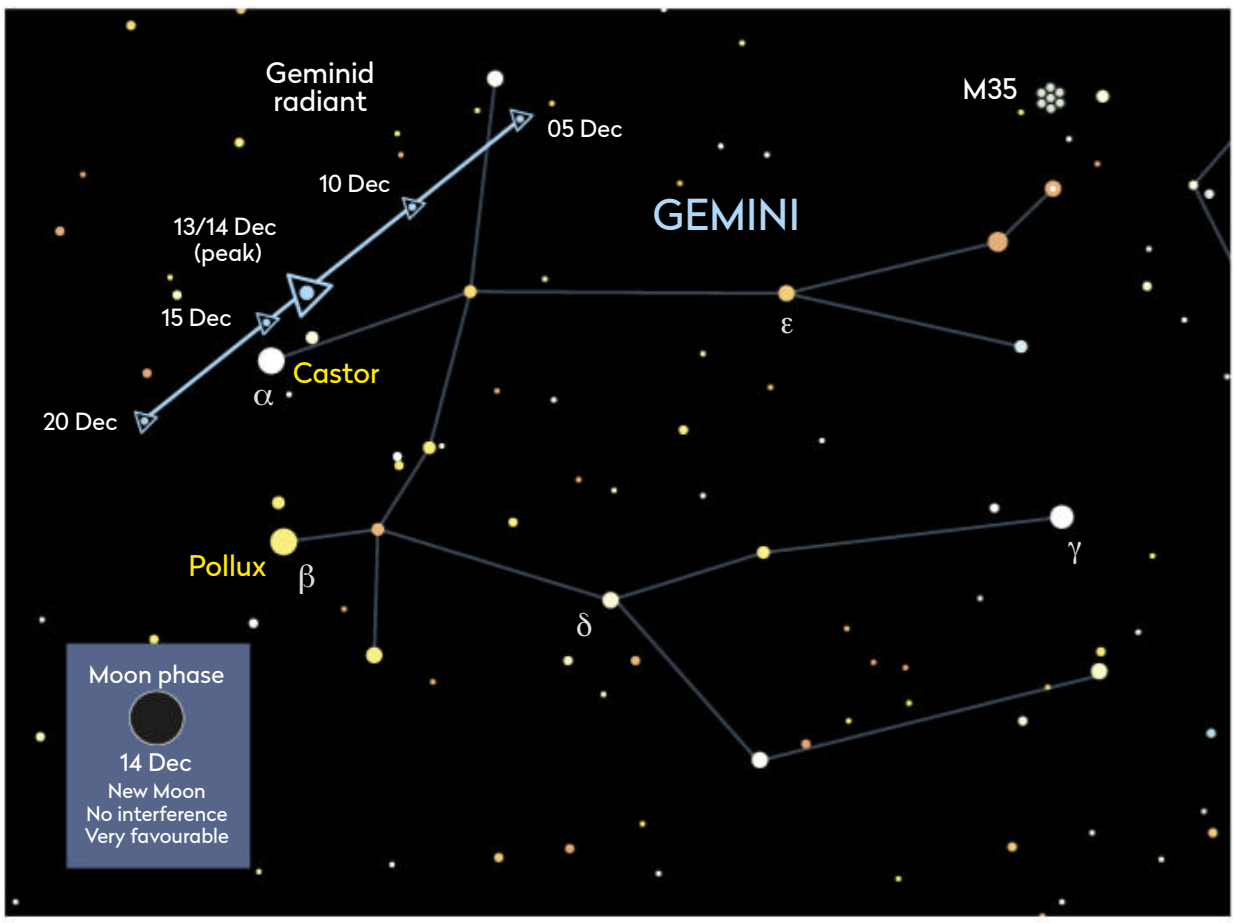
BEST TIME TO SEE:
Activity between 4–17 December, peak night 13/14 December

Which is the best meteor shower of the year? Most would probably say the August Perseids; with a peak zenithal hourly rate (ZHR) of 110 meteors per hour and occurring under the relatively balmy conditions of summer, what's not to like? However, this month's Geminid shower outstrips the Perseids in a number of ways. This may sound like a controversial statement but to explain it we need to look more closely at the often-misused value that is the zenithal hourly rate.

A shower's ZHR is a normalised value, a figure which compensates for all the issues that degrade a shower's visual performance. The ZHR considers how much of the sky you can, or cannot see; it takes account of the radiant's altitude and how clear your sky is. Applying the ZHR correction to the number of meteors seen over a set period gives you a figure which more accurately represents a shower's activity.

The Perseid shower has a peak ZHR of around 110 meteors per hour. The peak is narrow, just a few hours wide and varying slightly in terms of timing: the short nights of mid-August often place it within daylight for UK viewing. In contrast the Geminid peak is wider and, over recent years, its ZHR has been rising; currently, the Geminid peak is around 140–150 meteors per hour.

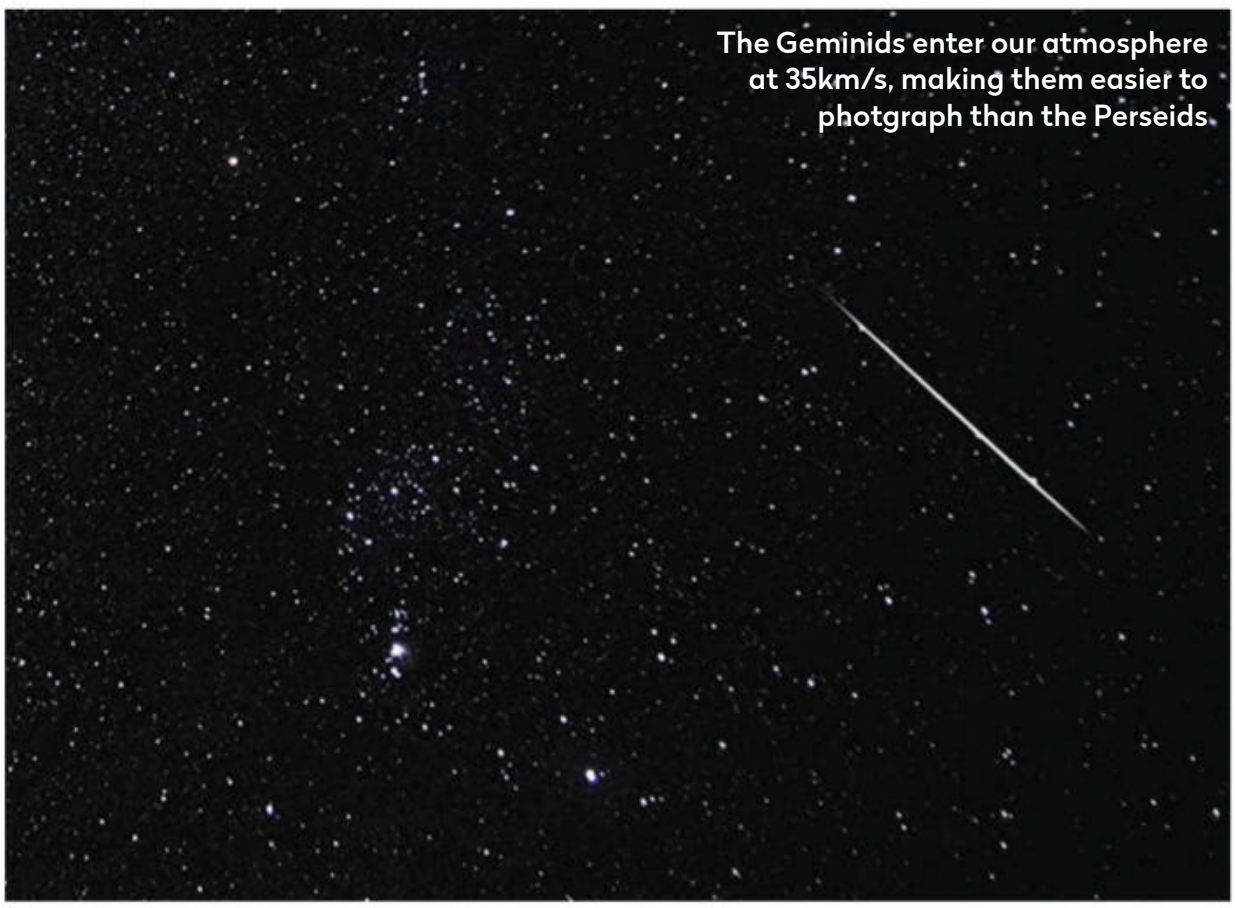
This year, the Geminid shower is expected to peak at 00:50 UT on 14 December, in the middle of a long, dark night. The radiant position is good too, culminating south at an altitude nearly 70° up around 02:00 UT. The height of a shower's radiant (where the it appears to originate, as viewed from Earth) is very important; for example, if a radiant is on the horizon, half of all trails would occur below the horizon. A radiant at the zenith is desirable (hence 'zenithal' hourly rate), but 70° up is pretty good.



▲ **All clear: on 14 December, the peak of the Geminids coincides with a new Moon**

Perseids make great photographic trails, typically showing a green colour transitioning to pink. Colour is one area where the Perseids pip the Geminids, the latter's trails typically appearing off-white. The Geminids do make up for this however. While the Perseids have an entry speed of 59km/s, the Geminids enter our atmosphere at 35km/s, producing slower trails which are easier to photograph. One caveat is the population index (r) value. Generally, the lower this shower-specific value is below 3, the greater the chance of brighter trails. For the Perseids the value of r is 2.2, for the Geminids 2.6.

This year's Geminid peak is favourable; as a new Moon occurs at 16:17 UT on the 14 December and will not interfere at all. With a well-timed peak, coinciding with a near maximum altitude radiant, this should be quite a show as long as the weather stays clear.



The Geminids enter our atmosphere at 35km/s, making them easier to photgraph than the Perseids

ALL PICTURES: PETE LAWRENCE

The Great Conjunction

BEST TIME TO SEE: 20, 21 and 22 December, narrowest separation on the 21st; view 40 minutes after sunset

Jupiter and Saturn have appeared close to one another since they crawled out of the morning twilight last February. After a brief divergence in the early summer months, since late August, to the naked eye they have steadily appeared to be getting closer.

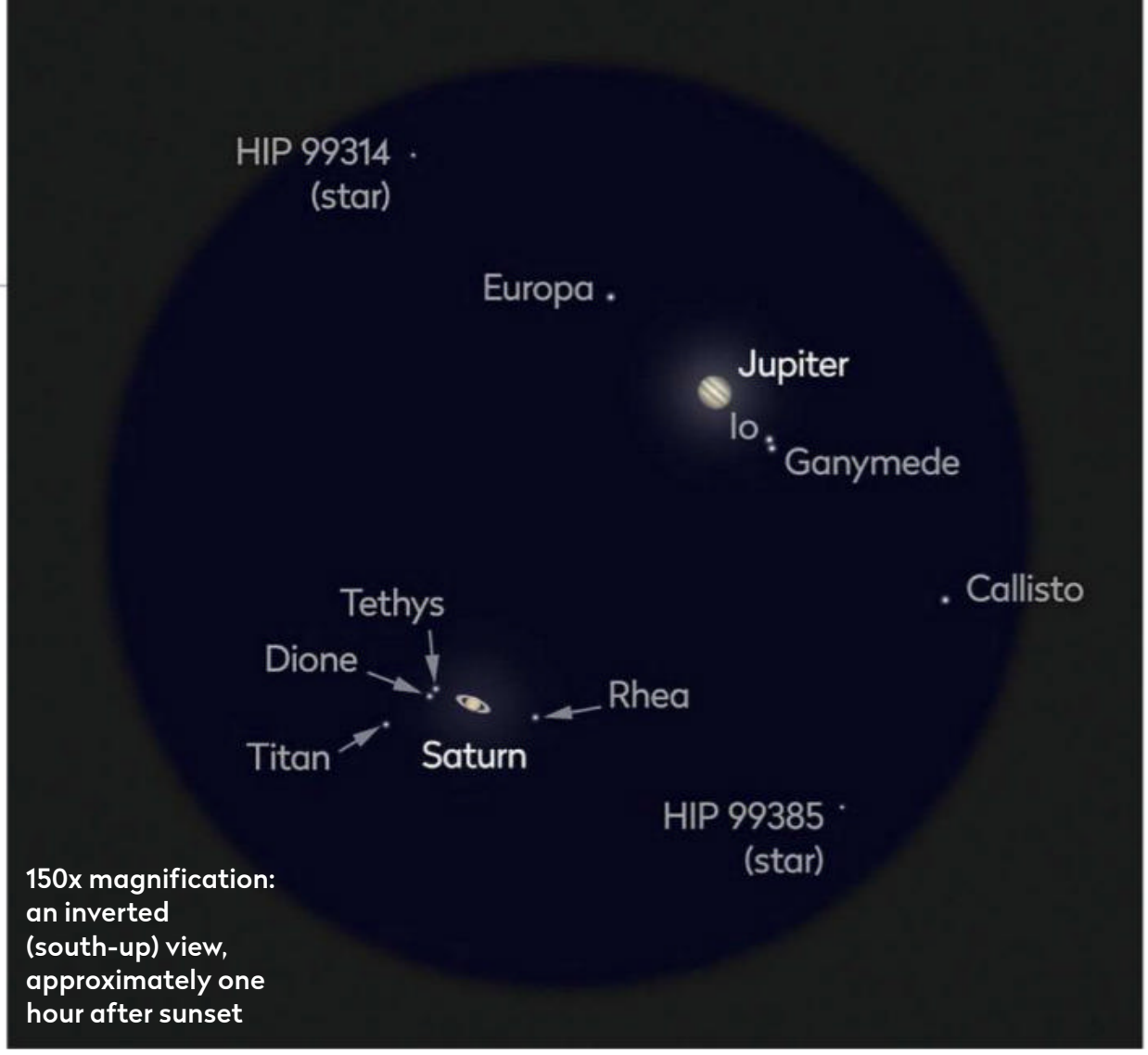
At the start of December, their separation will be 2.2°, and this gradually reduces over the month to reach a historically low 6.1 arcminutes on the evening of the 21st. To put this in context, the apparent diameter of the Moon is around 30 arcminutes. At their closest, Jupiter and Saturn will appear separated by just one-fifth the apparent size of the Moon. Visible shortly after sunset on the 21st, this 'Great Conjunction' will present the planets at their closest since July 1623!

At first glance with the naked eye, the planets will appear as one bright object, Jupiter's brightness at mag. –1.8 masking Saturn at mag. +0.9. But take a closer look and you may make out the fainter point of the Ringed Planet just above it.

Of course, their apparent proximity is simply due to line-of-sight; in reality, they are physically separated by 733 million km. But the sight of two bright planets so close to one another is something quite special.

A telescope will show both planets in the same field of view, each as a tangible disc. In order to do this, you'll need to use a magnification of 150x to 200x. Although the planets will appear small, this is a unique opportunity to see them and their brighter moons like this.

And speaking of natural satellites, the waxing crescent Moon will appear nearby on the evenings of 16 and 17 December, adding its own photogenic essence to the Great Conjunction.



150x magnification: an inverted (south-up) view, approximately one hour after sunset

▲ Don't miss December's Great Conjuction of Jupiter and Saturn; to see both planets at the same time through a telescope, you'll need a magnification of 150x to 200x

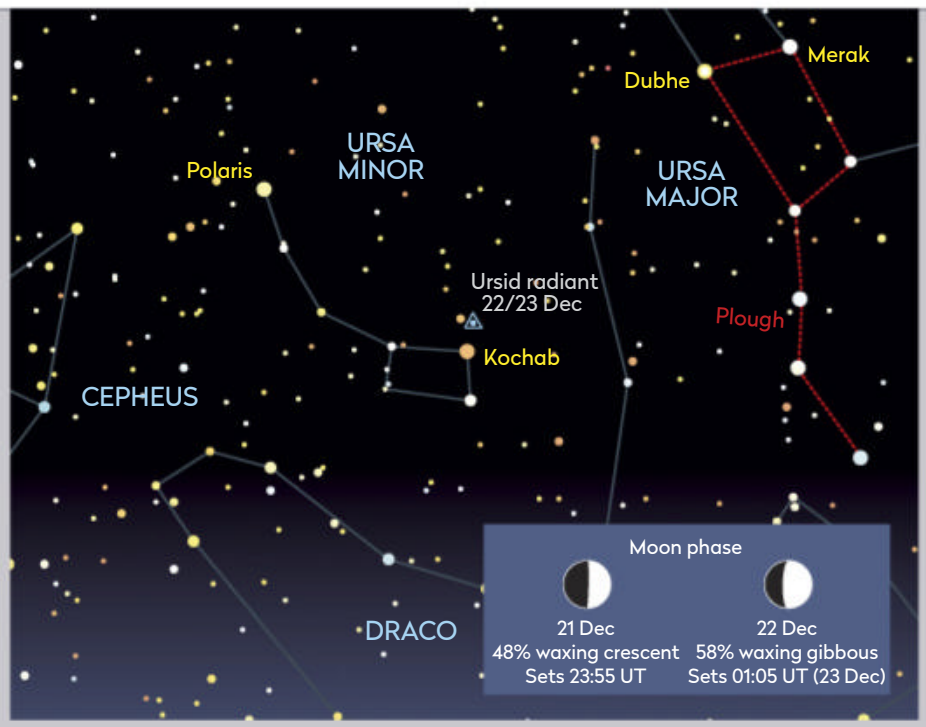
Ursid outburst?

BEST TIME TO SEE: Activity from 17–26 December, peak nights 21/22 and 22/23 December

While the Geminid shower grabs the December limelight, the Ursid shower tends to take a back seat. This year's Ursid peak occurs at 09:00 UT on the 22nd, providing peak observing opportunities on the nights of 21/22 and 22/23 December. The Moon will be close to first quarter at this time and will set early, leaving much of the remaining long, dark night for Ursid watching.

The peak zenithal hourly rate (ZHR) of the Ursid shower is around 10 meteors per hour and while this might not seem that tempting compared to the 140–150 of the Geminids, there is an alert for heightened activity this year, although not all predictions are favourable for the UK.

Three peaks of heightened activity have been predicted for 22 December, generally between 03:00–22:00 UT and specifically at 05:27 UT and 06:10 UT. The specific times of some of these peaks indicate that activity bursts may be short. However, for the three predictions mentioned here, the estimated ZHRs could be in the order of 420, 34 and 490 meteors per hour respectively.



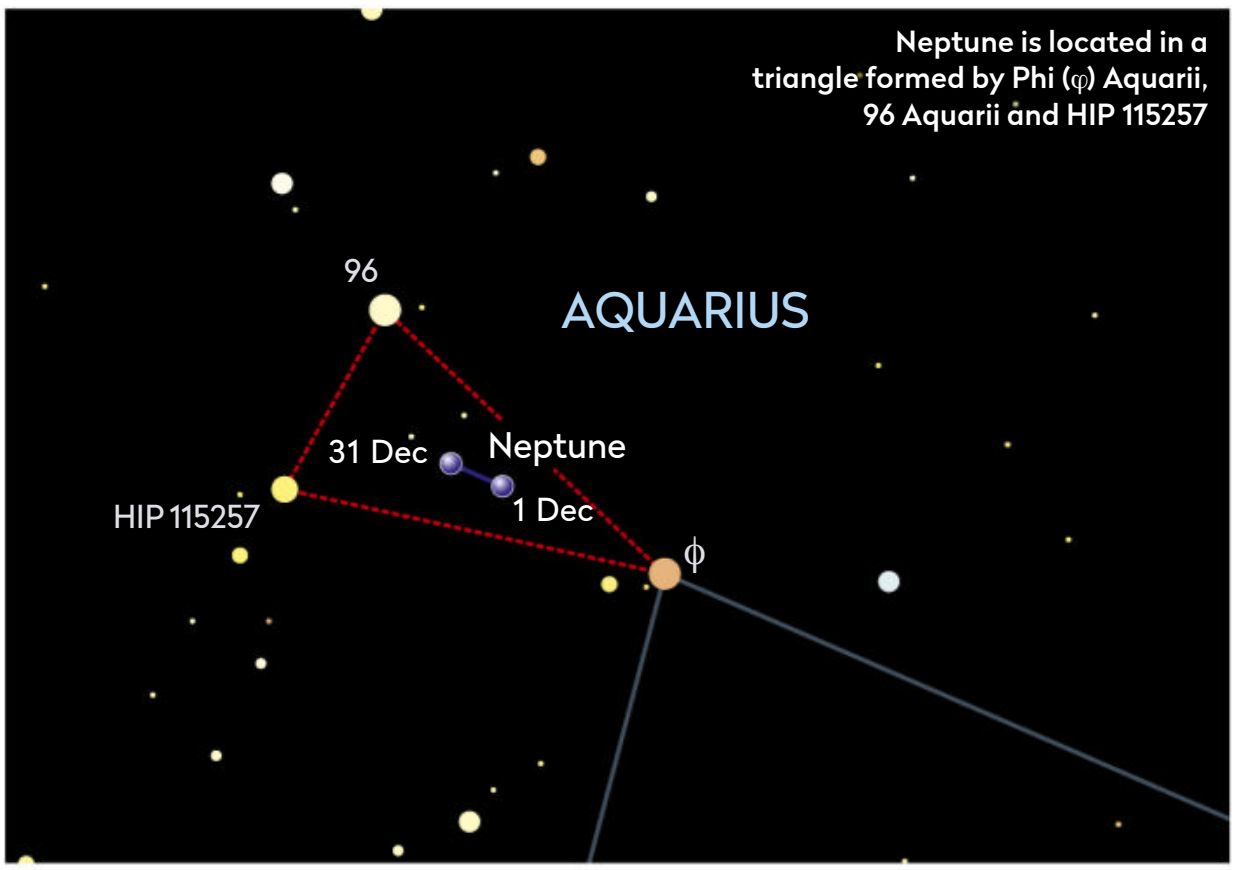
▲ The peak of the Ursid shower is at 09:00 UT on 22 December

Although it's tempting to identify peak night as the best time to go out and view a meteor shower, the important science requires monitoring for a whole period of activity. Only then can modelling be used to predict future outbursts.

PICK OF THE MONTH

Neptune

Best time to see: 1 December, 18:30 UT
Altitude: 31°
Location: Aquarius
Direction: South
Features: Small bluish disc, Triton
Recommended equipment: 150mm or larger



Neptune is located in a triangle formed by Phi (φ) Aquarii, 96 Aquarii and HIP 115257

Neptune is the outermost of the main planets. Having reached opposition on 11 September, it is now an evening object. For a nearby planet such as Mars, the period around opposition represents a time when the planet appears significantly larger and brighter than at other times. However, for more distant worlds such as Uranus and Neptune, the difference in brightness and size is fairly marginal. As Mars approached its best UK opposition for some time in the middle of October, it took priority in terms of amateur observing.

This month Neptune is well placed at the start of December, but it loses altitude against the evening twilight by the end of the month. At mag. +7.9 you'll need at least binoculars to see the planet, but these will only reveal it as a star-like point. A small telescope will show the planet's blue colour, with at least 150mm of aperture being required to reveal Neptune's tiny 2 arcsecond disc.

At present, Neptune is located east-northeast of mag. +4.2 Phi (ψ) Aquarii, within the confines of an isosceles triangle formed from Phi Aquarii, mag. +5.5 96 Aquarii and +6.2 HIP 115257. The planet appears to move away from the apex of this triangle (Phi Aquarii) towards the triangle's base throughout the month.

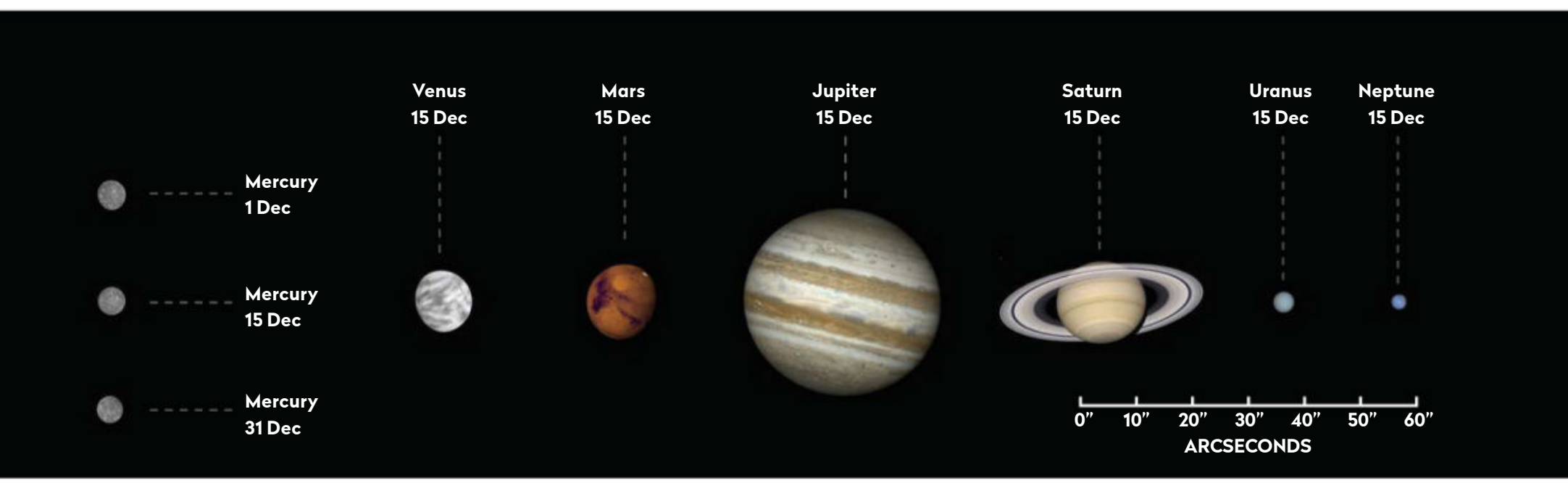
▲ Try and spot Triton, Neptune's largest moon, visible as a faint dot near the planet

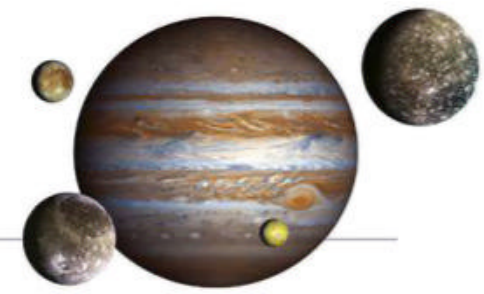
Although it's possible to see Neptune as a tiny disc, revealing any variation in its appearance remains the domain of large aperture telescopes or high-resolution planetary imaging setups. A less demanding target is Neptune's largest moon, Triton, which is currently shining at mag. +13.5. Use a large enough image scale and boost imaging exposure times to just over-expose the main planet, and Triton should become visible as a faint dot near the planet. This is best attempted when the seeing is fairly stable.

PETE LAWRENCE X 3

The planets in December

The phase and relative sizes of the planets this month. Each planet is shown with south at the top, to show its orientation through a telescope





Mercury

Best time to see: 1 December, 30 minutes before sunrise
Altitude: 2.5° (very low)
Location: Libra
Direction: Southeast

Mercury is bright at around mag. –0.7 during the first week of December, but its apparent distance from the Sun is decreasing so it's soon lost in the bright pre-sunrise sky. It reaches superior conjunction on the 20th and its late month reappearance into the evening twilight isn't very favourable.

Venus

Best time to see: 1 December, 90 minutes before sunrise
Altitude: 8° (low)
Location: Libra
Direction: Southeast

Venus is a prominent, albeit low, planet in the dawn twilight this month. It rises 2 hours and 40 minutes before the Sun at the month's start, shining at mag. –3.9 and showing an 88%-lit gibbous disc. By the month's close, Venus rises 1 hour and 30 minutes before the Sun, shines at mag. –3.8 and presents a 93%-lit 10 arcsecond gibbous disc through a scope.

Mars

Best time to see: 1 December, 20:30 UT
Altitude: 44°
Location: Pisces
Direction: South

Mars was at opposition on 13 October and is on the decline in terms of its appearance, but it's still bright and there's plenty to watch out for if you have a 200mm or larger scope. It lies in Pisces and shines at mag. –1.1 on 1 December, dropping to mag. –0.2 by the 31st. Through a scope Mars looks gibbous, with a phase varying between 92% on the 1st and 89% by the 31st. Mars shows a 14 arcsecond disc on the 1st, which shrinks to 10 arcseconds by month end.

Jupiter

Best time to see: 21 December, from 17:00 UT
Altitude: 8.5° (low)
Location: Capricornus
Direction: Southwest

Jupiter and Saturn reach their historic Great Conjunction on 21 December (see page 47). Both planets are now compromised by evening twilight, appearing low above the southwest horizon as darkness falls. Jupiter shines at mag. –1.8, while a waxing crescent Moon joins the scene, 5%-lit to the southwest of Jupiter on the 16th, and as an 11%-lit crescent southeast of the planet on the 17th.

Saturn

Best time to see: 21 December, from 17:00 UT
Altitude: 8.5° (low)
Location: Capricornus
Direction: Southwest

Saturn is partnered with Jupiter, having a close conjunction on the evenings of 20, 21 and 22 December. Both are visible from around 17:00 UT, appearing low above the southwest horizon. Saturn shines at mag. +0.9.

Uranus

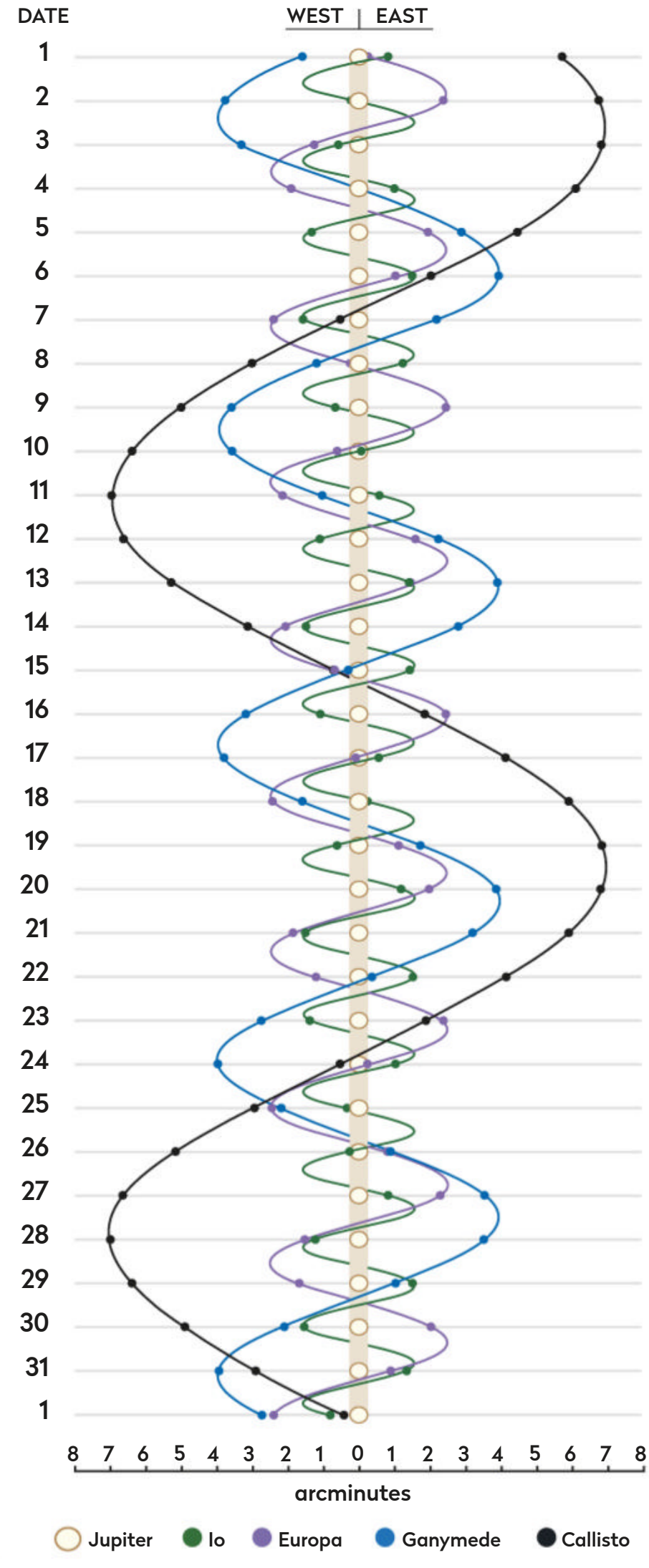
Best time to see: 1 December, 21:45 UT
Altitude: 50°
Location: Aries
Direction: South

Uranus remains well-positioned all month. Currently passing through the southern part of Aries, this distant ice giant is able to attain an altitude of 50° as seen from the UK, which makes it our best-positioned planet. It shines at mag. +5.7 which is just within naked-eye territory, but we'd recommend binoculars to see it.

More **ONLINE**
Print out observing forms for recording planetary events

JUPITER'S MOONS: DECEMBER

Using a small scope you can spot Jupiter's biggest moons. Their positions change dramatically during the month, as shown on the diagram. The line by each date represents 00:00 UT.



THE NIGHT SKY – DECEMBER

Explore the celestial sphere with our Northern Hemisphere all-sky chart

KEY TO STAR CHARTS

- Arcturus — STAR NAME
- PERSEUS — CONSTELLATION NAME
- GALAXY
- OPEN CLUSTER
- GLOBULAR CLUSTER
- PLANETARY NEBULA
- DIFFUSE NEBULOSITY
- DOUBLE STAR
- VARIABLE STAR
- THE MOON, SHOWING PHASE
- COMET TRACK
- ASTEROID TRACK
- STAR-HOPPING PATH
- METEOR RADIANT
- Circlet — ASTERISM
- PLANET
- QUASAR

STAR BRIGHTNESS:

- MAG. 0 & BRIGHTER
- MAG. +1
- MAG. +2
- MAG. +3
- MAG. +4 & FAINTER
- COMPASS AND FIELD OF VIEW
- MILKY WAY

When to use this chart

1 December at 00:00 UT
15 December at 23:00 UT
31 December at 22:00 UT

On other dates, stars will be in slightly different positions because of Earth's orbital motion. Stars that cross the sky will set in the west four minutes earlier each night.

How to use this chart

1. Hold the chart so the direction you're facing is at the bottom.
2. The lower half of the chart shows the sky ahead of you.
3. The centre of the chart is the point directly over your head.

Sunrise/sunset in December*

Date	Sunrise	Sunset
1 Dec 2020	08:03 UT	15:55 UT
11 Dec 2020	08:16 UT	15:51 UT
21 Dec 2020	08:24 UT	15:53 UT
31 Dec 2020	08:26 UT	16:01 UT

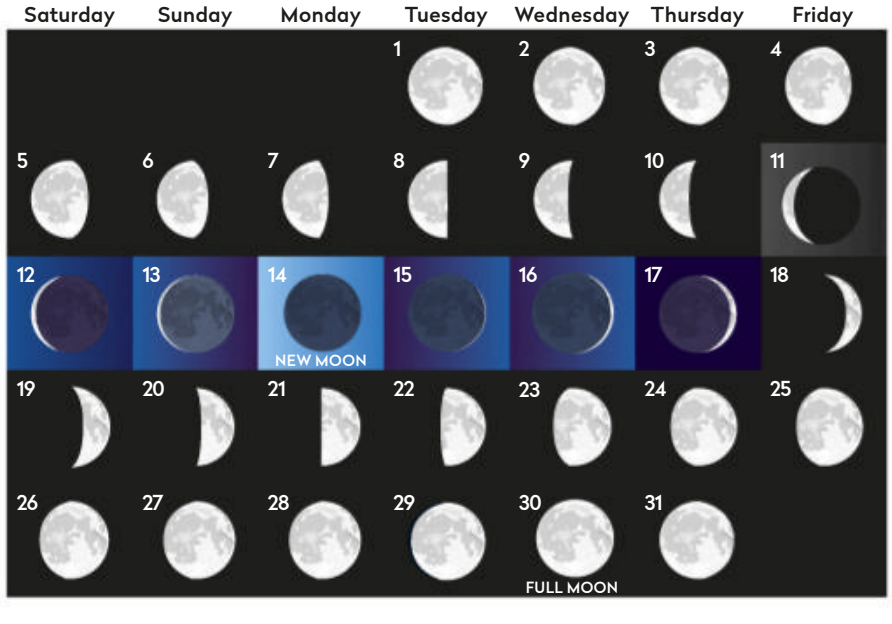
Moonrise in December*

Moonrise times

1 Dec 2020, 16:37 UT	17 Dec 2020, 11:09 UT
5 Dec 2020, 20:38 UT	21 Dec 2020, 12:36 UT
9 Dec 2020, 00:43 UT	25 Dec 2020, 13:28 UT
13 Dec 2020, 06:36 UT	29 Dec 2020, 15:16 UT

*Times correct for the centre of the UK

Lunar phases in December



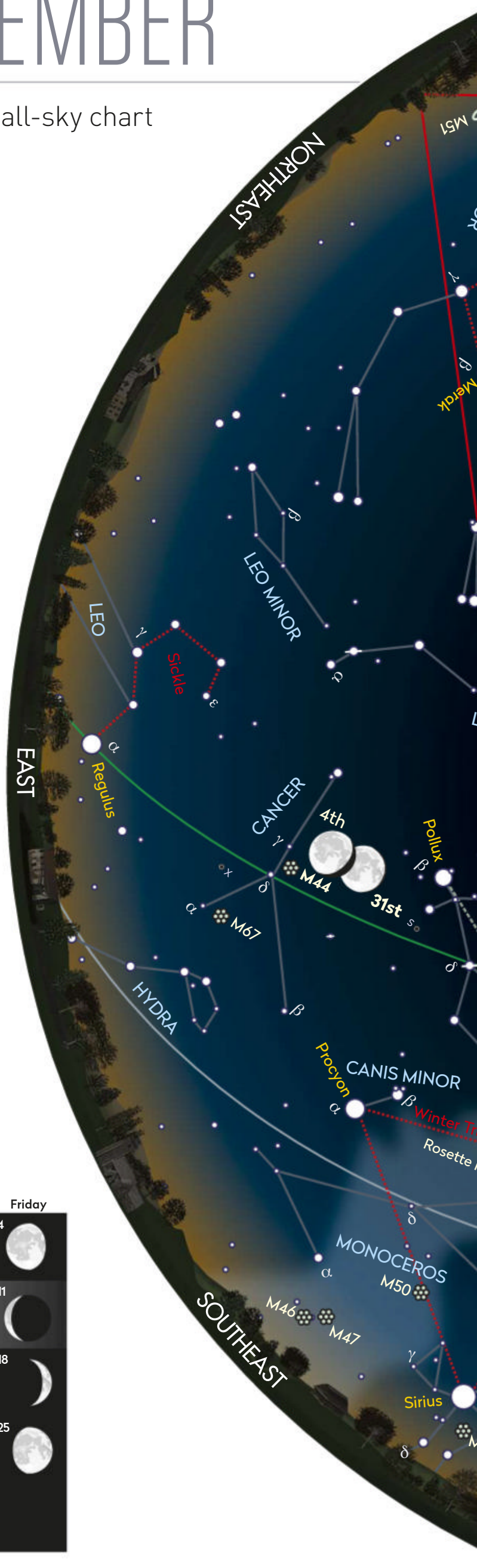
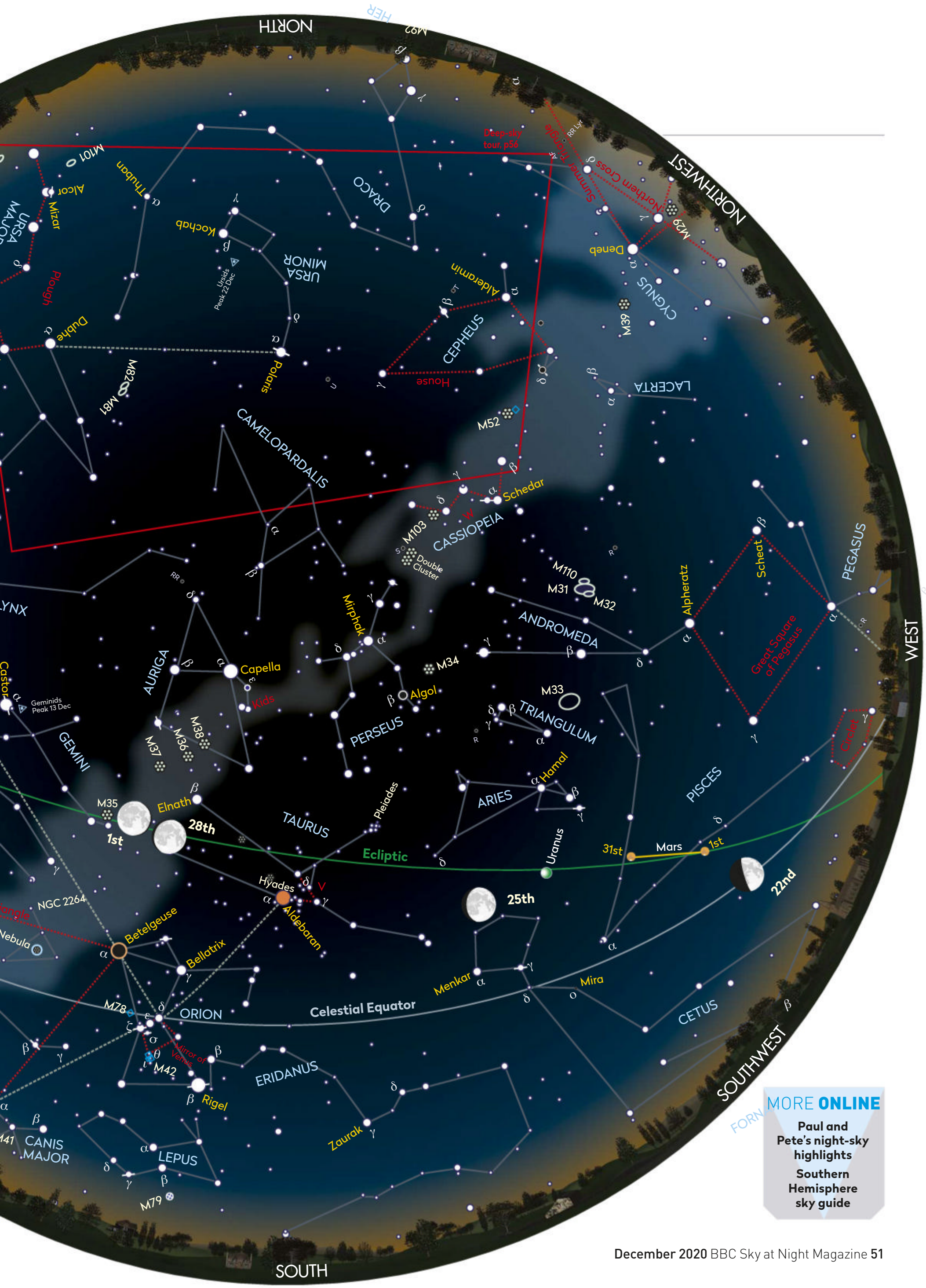


CHART: PETE LAWRENCE



MORE **ONLINE**

Paul and Pete's night-sky highlights

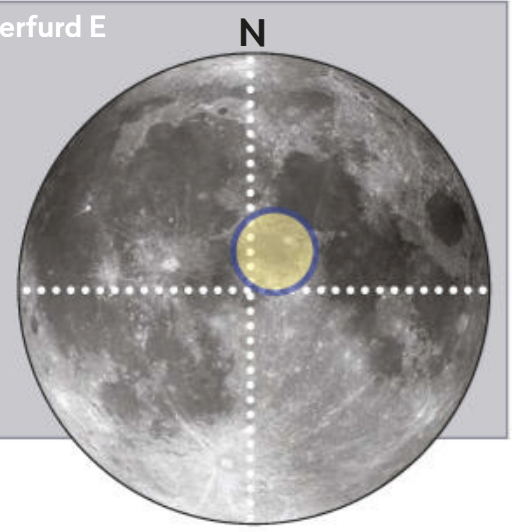
Southern Hemisphere sky guide

MOONWATCH

December's top lunar feature to observe

Mare Vaporum

Type: Lunar Sea
Size: 270km x 400km
Longitude/latitude: 4.1° E, 13.2° N
Age: Older than 3.9 billion years
Best time to see: First quarter (21-23 December) or 6 days after full Moon (6-7 December)
Minimum equipment: 10x Binoculars



Unlike its neighbouring seas which frame it well, **Mare Vaporum** or the Sea of Vapors lacks a well-defined boundary. In this it is unlike Mare Imbrium to the northwest, Serenitatis to the northeast and Tranquillitatis to the east; instead 270km x 400km Vaporum appears as an irregular dark patch.

A dark volcanic region known as **Pyroclastic 'Mare Vaporum'** dominates the southeast corner. To the south is the wonderful form of the **Rima Hyginus**, a curious collection of 1–4km craterlets and rilles that form two lines at an angle to one another, either side of 10km **Hyginus**. The appearance of the crater lines and Hyginus is reminiscent of a large bird flying directly towards you. The multitude of small craterlets and the rille, or narrow channel, that connects them is also thought to have volcanic origins.

The western end of the rille creeps into the southern region of Mare Vaporum to the south of 5km crater **Hyginus D**, which also marks the western edge of the pyroclastic region. Vaporum's southwest edge is reasonably well defined to the north of the triangular 23km crater **Ukert**. It leads towards the western boundary, which becomes chaotic once again with a region of dark material known as **Pyroclastic 'Rima Bode'**. The distinctive 18km crater **Bode** lies 122km west and south of Ukert. **Bode A** (12km) and **Bode B** (10km) sit directly south of Pyroclastic 'Rima Bode', easy targets for a 100mm scope. More challenging is **Bode K** (6km), which sits to the north of the mid-point of the line joining Bode A to Bode B.

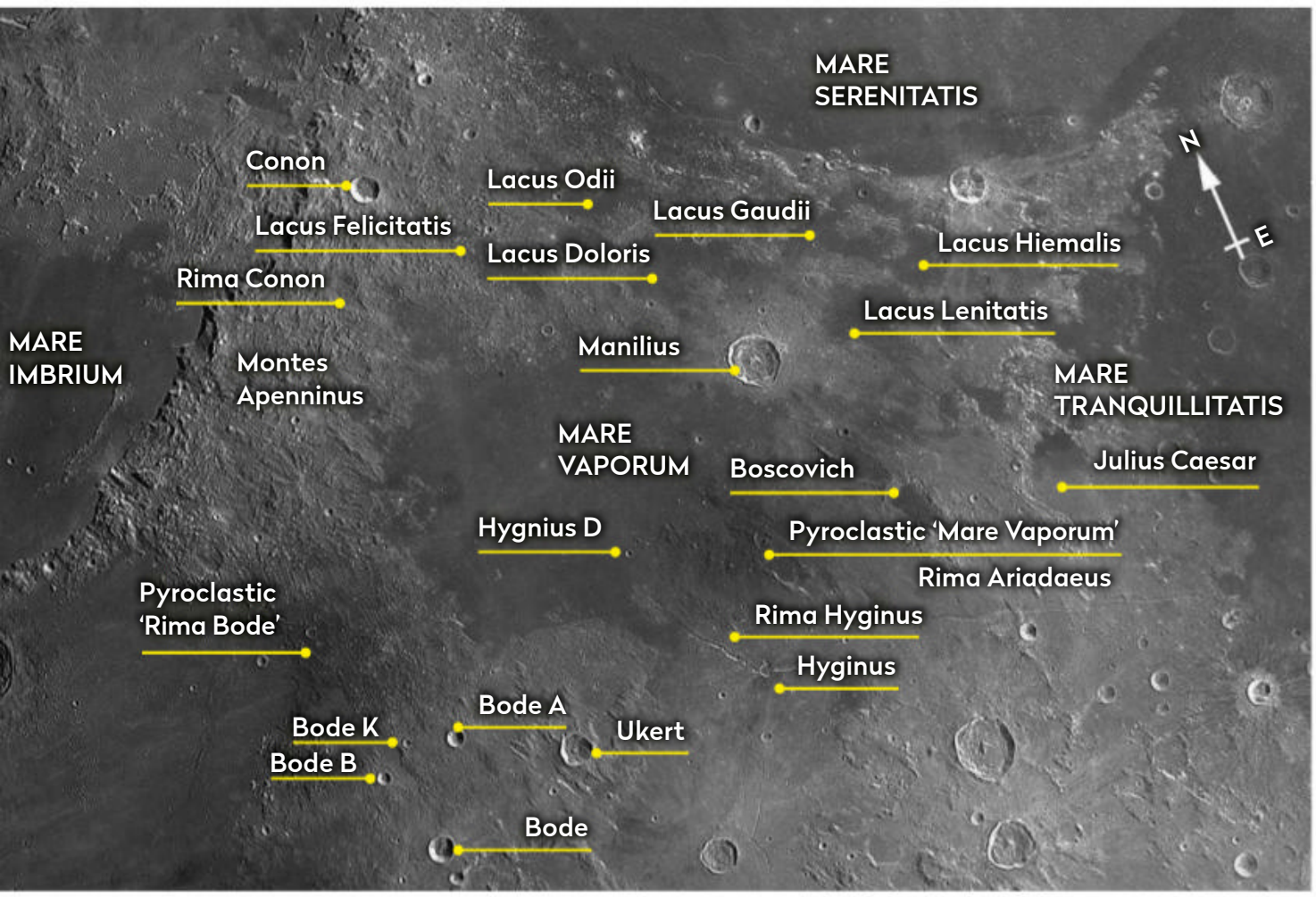
Heading north we enter a portion of Mare Vaporum's boundary defined by the foothills of **Montes Apenninus**. This majestic mountain range defines the southeast border of the giant Imbrium Basin to the northwest, and is quite magnificent to observe when the Sun is low in its sky, around the same time as it is for Mare Vaporum. The largest crater visible north of Mare Vaporum and slightly south of Montes Apenninus is 22km **Conon**. Look 90km to the south of Conon's centre and there's a challenging rille known as **Rima Conon**. Measuring 45km in length and just 2km wide, this requires a 300mm scope to see convincingly.

Vaporum lacks a well-defined boundary, instead appearing as an irregular dark patch

The foothill boundary becomes indistinct as you sweep around the northern edge of Mare Vaporum. Here, lava has infilled some of the elevated terrain to form lunar lakes such as 70km **Lacus Odii** (Lake of Hate), 111km x 80km **Lacus Doloris** (Lake of Sorrow), 121km x 100km **Lacus Gaudii** (Lake of Joy) and 90km x 90km **Lacus Felicitatis** (Lake of Happiness).

Sitting between these lakes and Mare Vaporum is the sharply defined form of 40km **Manilius**. Its irregular rim leads down to a ledge feature before dropping to the crater floor proper. A small central mountain complex sits at its centre. 151km to the south-southeast of Manilius is the irregularly shaped, flat-floored 46km crater **Boscovich**, dwarfed by 90km **Julius Caesar**, 110km to the east. Julius Caesar almost looks like a scaled-up version of Boscovich, they are so similar. Just to their south is the long, narrow form of **Rima Ariadaeus**, which at 220km long and 7km wide can be seen with a 100mm instrument.

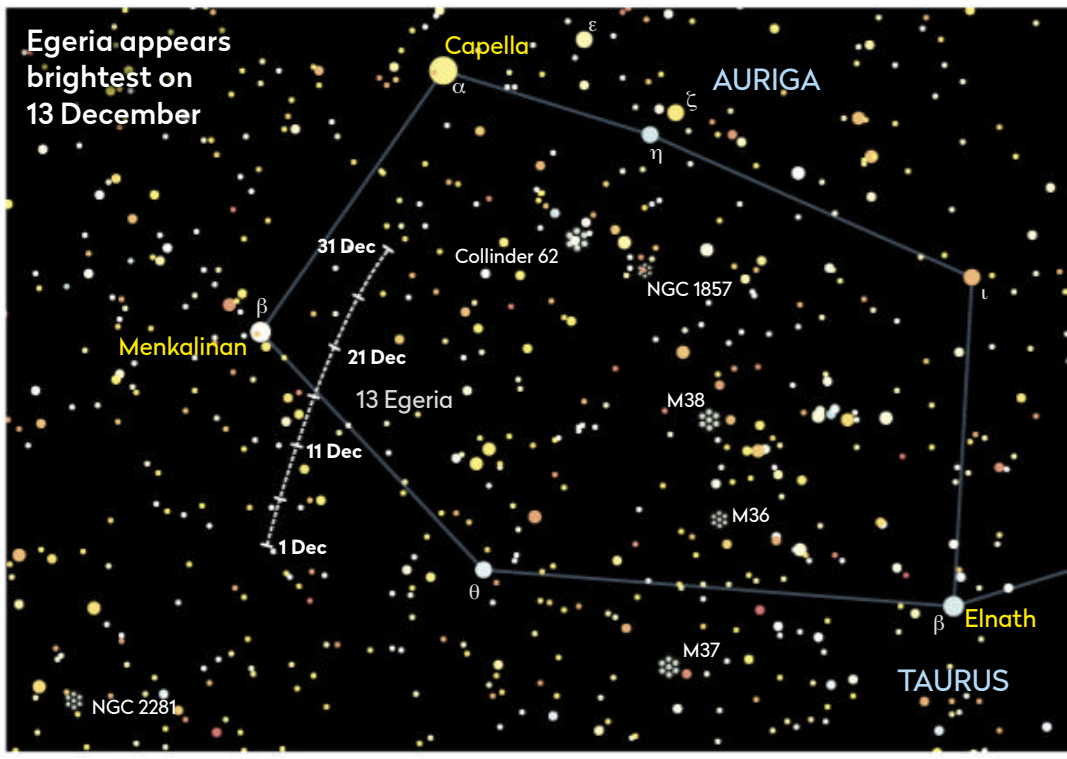
PETE LAWRENCE X 3



▼ **The Montes Apenninus range, to the west of Mare Vaporum, is best viewed when the terminator is nearby**

COMETS AND ASTEROIDS

View minor planet 13 Egeria as it reaches opposition in the constellation of Auriga



Minor planet 13 Egeria reaches opposition this month, high in the sky in the constellation of Auriga, The Charioteer. Its brightness varies little throughout December, beginning the month at mag. +10.2, brightening to +10.0 by the 13th, before starting to dim again on the 27th. Egeria begins its track through Auriga 3.3˚ east of the mid-point of the line joining Menkalinan to Theta (θ) Aurigae. From here it tracks northwest to pass 2˚ south of Menkalinan on the night of 15/16 December, ending the month just over a degree south of the mid-point between Capella and Menkalinan.

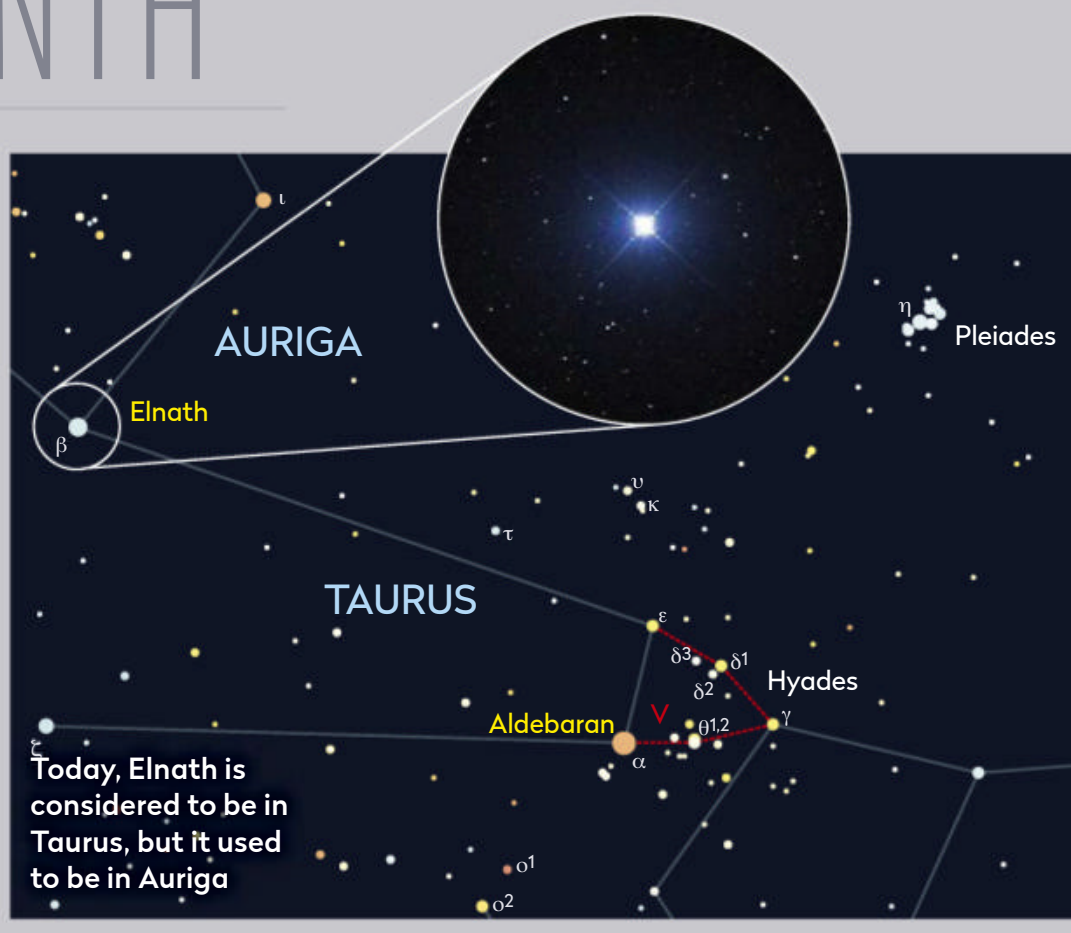
Named after a mythological nymph, Egeria was discovered by Annibale de Gasparis on 2 November 1850. It's a main belt asteroid, orbiting between a perihelion distance of 2.36 AU and an aphelion distance of 2.79 AU. It takes 4.14 years to complete each orbit and rotates on its axis once every 7.05 hours. It's a dark object, with an albedo (reflectivity) of 0.0825, and belongs to the G-type class of asteroids. This is a relatively uncommon type of carbonaceous asteroid making up just 5 per cent of their total population.

Egeria has occulted two stars in recent times. The first, on 8 January 1992, gave us a physical size for the body of 217km x 196km; the second, 16 years later on 22 January 2008, then made it possible to refine its size to a smaller 214.8km x 192.0km.

The inclination of Egeria's orbit is 16.554˚, which is why it's able to appear well away from the ecliptic which passes nearby through Taurus, to track through the more northern constellation of Auriga. Egeria's brightness varies between mag. +9.7 and mag. +12.5, this month's appearance being quite favourable.

STAR OF THE MONTH

Spot Elnath, Taurus's northern horn tip



Elnath (Beta (β) Tauri) is the second brightest star in the constellation of Taurus, the Bull, and represents the northern horn tip of the creature. On star charts it is an oddity, commonly shown with connecting lines not just to Taurus, but also to Auriga, which lies further north. Other such switchovers are also present in the night sky, but these are often due to the formalisation of constellation boundaries from 1930.

In the case of Elnath, a name which means 'the butting', the star was allocated to both constellations by Ptolemy and Johann Bayer, who labelled it as both Beta (β) Tauri and Gamma (γ) Aurigae, a star with two identities! The latter name was dropped in 1930 during the process of boundary formalisation.

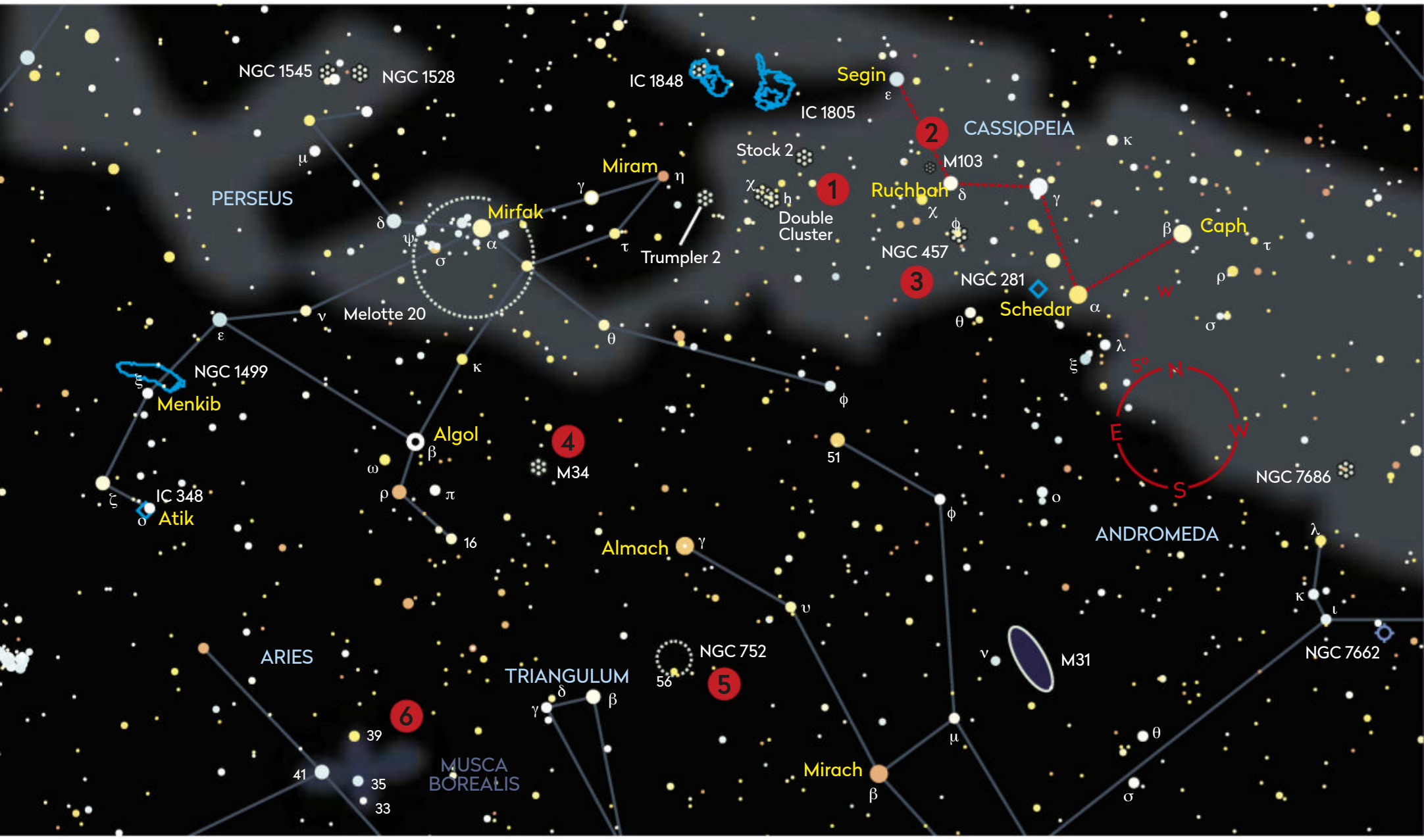
An interesting fact related to Elnath's position in the sky, is that it lies close to the 'Galactic anti-centre'. This is the position in the sky you would arrive at if you projected a line from the centre of our Milky Way Galaxy through the Sun and out the other side. The star sits just 3˚ west of this point.

Elnath shines at mag. +1.7 and is a hot, blue-white giant star of spectral type B7III. It is 4.2 times larger than our Sun and shines with a luminosity 700 times as great. It appears to have an abundance of manganese 25 times greater than the Sun, but also has a deficit of magnesium and mercury, its abundance of these elements being just one-eighth of the Sun's. Elnath lies at a distance of 134 lightyears and, like our Sun, appears to be a solitary star, devoid of any gravitationally bound companions, although there is a faint line-of-sight star 33.4 arcseconds away.

BINOCULAR TOUR

With Steve Tonkin

The Double Cluster and Owl Cluster are among December's wide-field sights



1. Perseus Double Cluster

10x50 The Double Cluster is nice and high in December evenings, so you'll probably be able to see it with your naked eye, about one-third of the way from Miram (Eta (η) Persei) to Ruchbah (Delta (δ) Cassiopeiae). 10x50 binoculars transform a single fuzzy patch into an elongated glow with two cores of brightness. Some multicoloured chains of stars lead away from the Double Cluster; it's worth following them to see where they lead. ☐ **SEEN IT**

2. M103

15x70 Get Ruchbah in the middle of your field of view and about 1° to the east you'll see a small (6 arcminute across) triangular glow that stands out from the Milky Way. Although it has a Messier number, M103 is one of more than 20 objects in Messier's catalogue that was found by Pierre Méchain. What appears to be the cluster's brightest star is a foreground star, not a cluster member. ☐ **SEEN IT**

3. The Owl Cluster (NGC 457)

15x70 Use Ruchbah to identify mag. +4.3 Marfak-East (Theta (θ) Cassiopeiae) and pan 2° towards it. Here you'll find a double star with its components shining at mag. +5.0 and +7.0, separated by 135 arcseconds. These are the Owl's eyes and, as with our previous target, the brighter one, Phi (ϕ) Cassiopeiae, is a foreground object. Its body and wings are comprised of 9th and 10th magnitude stars. ☐ **SEEN IT**

4. M34

10x50 You'll find M34 about 5° (one field of view in 10x50s) from Algol (Beta (β) Persei) in the direction of Almach (Gamma (γ) Andromedae): you are seeking a fuzzy patch that has a similar apparent size to the Moon. Your 10x50s should resolve 12 or more stars, the brightest of which form a distorted 'H'-shape. You are looking at starlight that left this 220 million-year-old, 14 lightyear-diameter cluster about 1,400 years ago. ☐ **SEEN IT**

5. NGC 752 and 56 Andromedae

10x50 Locate Beta (β) Trianguli, place it at the bottom of the field of view, and NGC 752 should appear near the top – just to the left of the close pair of 6th magnitude deep yellow stars that is 56 Andromedae. NGC 752 is twice the diameter of M34 and you should be able to resolve several yellowish stars; these hint at its great age, nearly 2 billion years old. ☐ **SEEN IT**

6. Musca Borealis

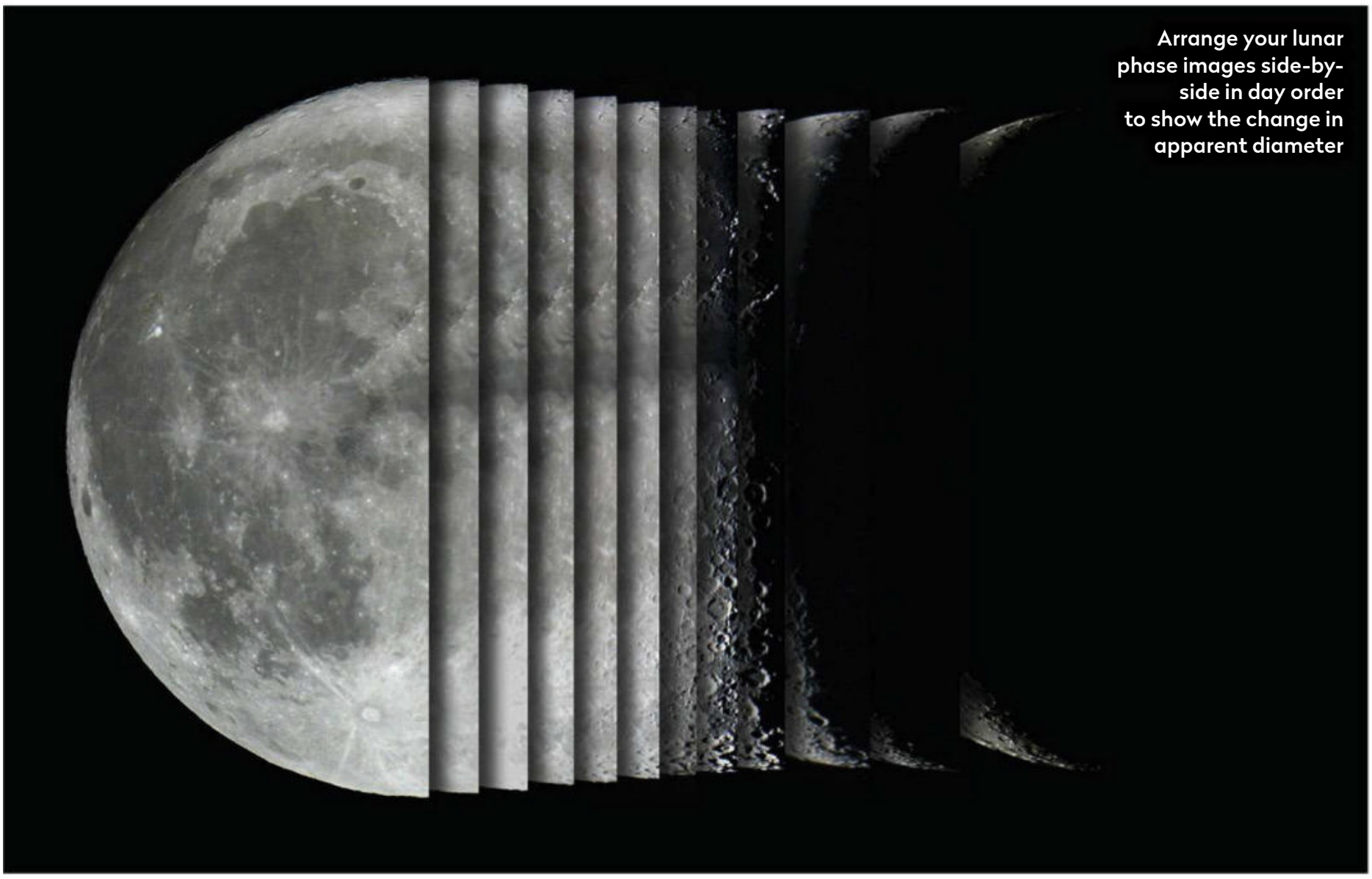
10x50 This defunct constellation of four naked-eye stars has been variously identified as a bee, a wasp, a fly and a fleur-de-lis. Your binoculars will not only reveal the variety of colours in these stars, but also the chain of fainter stars of which the two more southerly stars, 33 and 41 Arietis, are members. White 41 Arietis is a wide double star with a yellow-orange companion. ☐ **SEEN IT**

☑ Tick the box when you've seen each one

PETE LAWRENCE X 3

THE SKY GUIDE CHALLENGE

Can you track the variation in the Moon's apparent diameter over a month?



Arrange your lunar phase images side-by-side in day order to show the change in apparent diameter

The Moon is amazing to study and this month's challenge is to reveal something interesting about the physicality of its orbit. Studying the Moon as a whole can reveal effects which may normally be overlooked.

Its most obvious effect is the ever-changing phase caused by the varying Sun-Moon-Earth angle. From thin waning and waxing crescents to the sky-obscuring glare of a full Moon, the phase-cycle is an integral part of our lives. The Moon's orbit also gives us the daily tide cycle.

But there's another effect that may not be so obvious, which comes about because the distance between you and the Moon is not constant. The variation occurs in two ways. The first is connected with moonrise and moonset, when the Moon is physically slightly further from you than if it were overhead. Technically, the Moon would be closest if you could draw a straight line between it, you and Earth's centre, but when rising or setting, the Moon is approximately an Earth radius further away than when positioned at its closest possible position. The difference comes to several thousand kilometers, yet although sizeable, it only has a small effect on the Moon's apparent size. The Moon appears a little smaller when low down – and this is countered by the optical effect known as the Moon illusion in any case.

Attempt to image the Moon for every day over the course of a month

A more significant variation comes from the Moon's elliptical orbit. Here the difference between the perigee (closest) and apogee (furthest) distance is significant at around 43,000km. Lunar perigee occurs once every lunar orbit, about once a calendar month, and on the three or four times a year this coincides with a full or new Moon it's known as a supermoon.

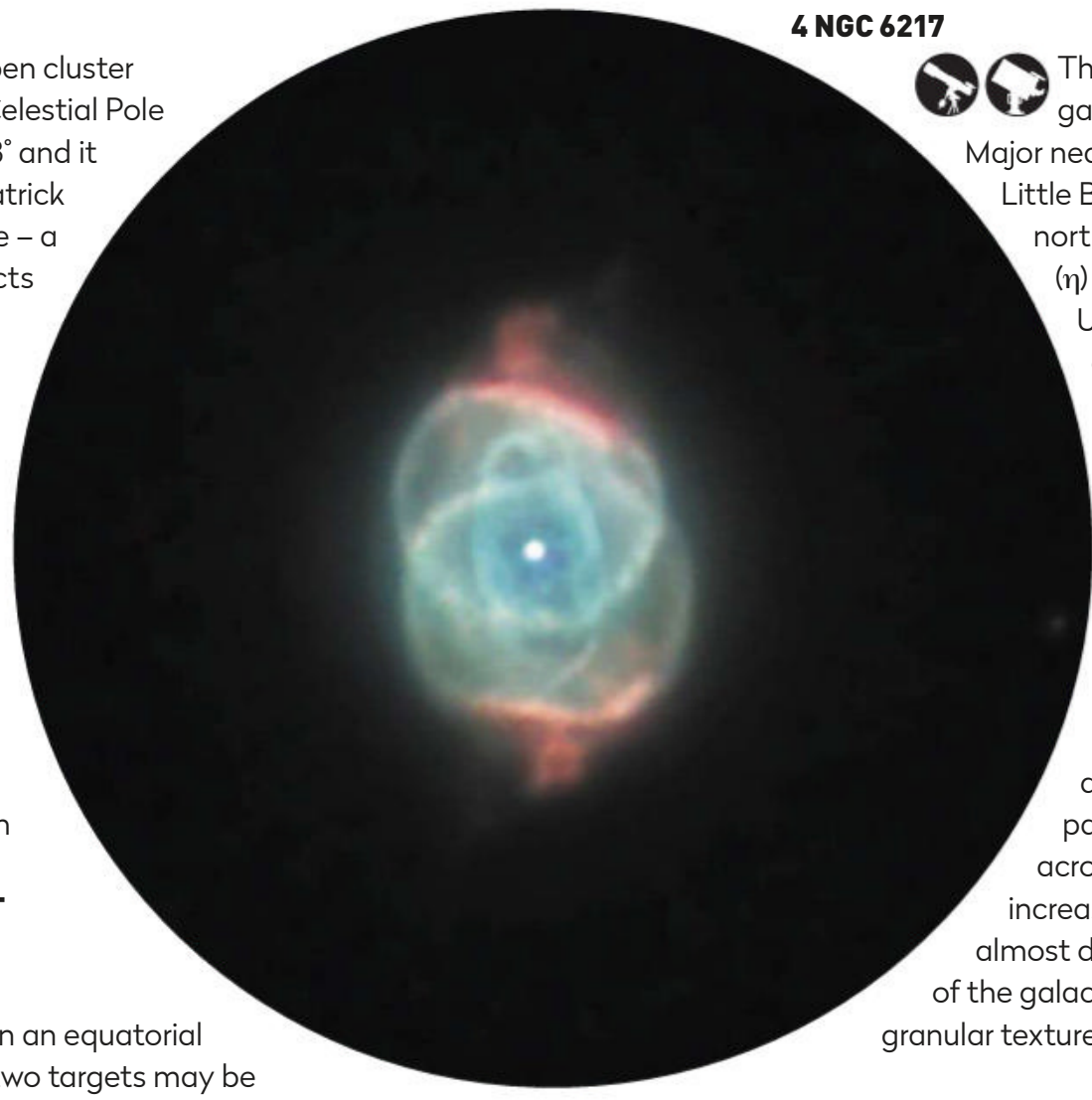
To show this variation, you need to image the Moon with a telescope or telephoto lens that can produce a lunar image which fills at least half the imaging frame of a digital camera. Then attempt to image the Moon every day over the course of a month (this is the hard part as the weather will interfere). Make sure the setup is the same for all the shots you obtain.

Once you've collected as many phase images as possible, open them in a program like GIMP and rotate each disc so the Moon's 'centre-line' is vertical. This is easy to determine for crescent Moons, as it's the imaginary line connecting the crescent's two points. For gibbous phases it can be trickier, but still fairly obvious.

Arrange the images to show the Moon's apparent diameters as close as possible to side-by-side, like in our image, lining them up in day order. Amazingly, this simple comparative arrangement shows something quite incredible: the periodic variation in the apparent diameter of the Moon caused by its continually varying distance from Earth.

DEEP-SKY TOUR

We set off from Polaris for a celestial treasure hunt around the North Celestial Pole



▲ Finish this month's tour with NGC 6543, the Cat's Eye Nebula

JOHANNES SCHEDLER/CCDGUIDE.COM, CHART BY PETE LAWRENCE

1 NGC 188

NGC 188 is an open cluster near the North Celestial Pole (NCP). Its declination is 85.3° and it sits 4° south of Polaris. In Patrick Moore's Caldwell Catalogue – a list of bright deep-sky objects organised by declination – it's listed as Caldwell 1. The best way to visualise NGC 188's location is to imagine it in a squat isosceles triangle, Polaris at the top, mag. +4.3 Delta (δ) Ursae Minoris at one base vertex and NGC 188 at the other in the direction of Cassiopeia. It has an apparent diameter of 0.25° and shines at eighth magnitude. It suits a low power eyepiece. ☐ **SEEN IT**

2 NGC 2276

If your scope is on an equatorial mount, our first two targets may be tricky; the irony of near-NCP viewing is that although movement due to Earth's rotation is minimised, many equatorial mounts have difficulty pointing so close to the pole. Interestingly, Delta (δ) Ursae Minoris, NGC 188 and NGC 2276 all sit 4° from Polaris. Rotate anti-clockwise around Polaris for 111° from Delta to get to NGC 188, and a similar rotation to get to NGC 2276.

This galaxy has a visual magnitude of +10.6 but low surface brightness. It's just about visible with a 250mm scope, sitting close to a mag. +8.5 star, 2 arcminutes to the west-southwest. The mag. +12.1 lenticular galaxy NGC 2300 sits 5 arcminutes to the east of NGC 2275 and although it has a lower listed magnitude, is easier to spot due to higher surface brightness. ☐ **SEEN IT**

3 IC 3568

Extend the line from NGC 188 through Polaris for twice the distance again to arrive at the planetary nebula IC 3568 in Camelopardalis. This has a visual magnitude of +10.6. It best suits larger apertures over 300mm in diameter. IC 3568 appears nicely concentrated through the eyepiece; there's a bright inner core approximately 12 arcseconds across with a an outer halo extending to 20 arcseconds. ☐ **SEEN IT**

4 NGC 6217

The mag. +11.2 barred spiral galaxy NGC 6217 lies in Ursa Major near the 'box' defining the Little Bear's rump. Locate the two northern stars in the box, Eta (η) Ursae Minoris and Zeta (ζ) Ursae Minoris. Imagine these as the base of an equatorial triangle pointing towards the northeast, the northeast vertex marking the position of NGC 6217.

A small scope will show this object as a faint patch with a stellar centre. Increasing the aperture to 250mm shows a more elongated, brighter patch about 1.5 arcminutes across. A 300mm instrument increases the apparent size, almost doubling what you can see of the galactic target and revealing a granular texture in the core. ☐ **SEEN IT**

5 NGC 6340

We hop into Draco for our last two objects, the penultimate being NGC 6340, an 11th magnitude unbarred spiral galaxy. Apertures below 250mm show a small circular object, roughly 1 arcminute in diameter. The core is bright here, and definitely a disc rather than a point of light. A mag. +11.2 red-coloured star sits 2 arcminutes northwest of the galaxy. Increasing aperture brings a larger apparent size to the object, increasing its size by about 70 per cent. The core is well defined, around two-thirds of an arcminute across, and shows no real structure, appearing like an evenly illuminated disc of light. NGC 6340 is around 55 million lightyears away. ☐ **SEEN IT**

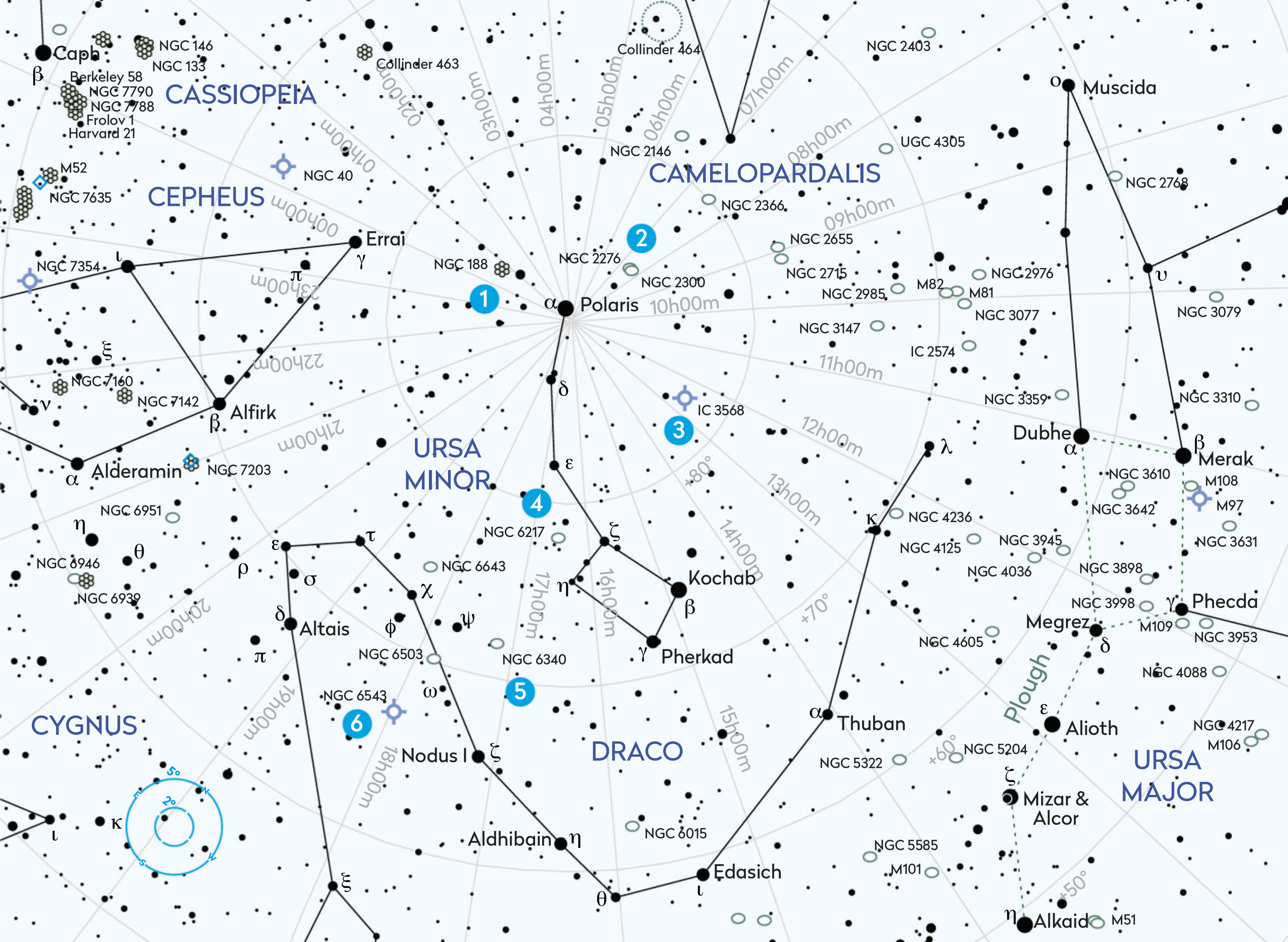
6 NGC 6543

Our final object is a lovely planetary nebula known as NGC 6543, the Cat's Eye Nebula. Shining at mag. +8.1, it has a good surface brightness and is a viable target for smaller apertures, although don't expect too much detail below 250mm. At low powers it's easy to mistake it for a star. One way to reveal it is to flip an OIII filter across the view: this will cause the stars to blink out while the nebula remains visible. The colour is striking with a definite blue-green hue. Once you've identified the object, pile on the power. A 150mm scope reveals an elongation to its shape, 250mm revealing a degree of asymmetry to the elongation. Powers over 350x may show bright spots around the periphery. The beautiful Cat's Eye Nebula is located 3,600 lightyears from Earth. ☐ **SEEN IT**

This Deep-Sky Tour has been automated ASCOM-enabled Go-To mounts can now take you to this month's targets at the touch of a button, with our Deep-Sky Tour file for the EQTOUR app. Find it online.

More **ONLINE**

Print out this chart and take an automated Go-To tour. See page 5 for instructions.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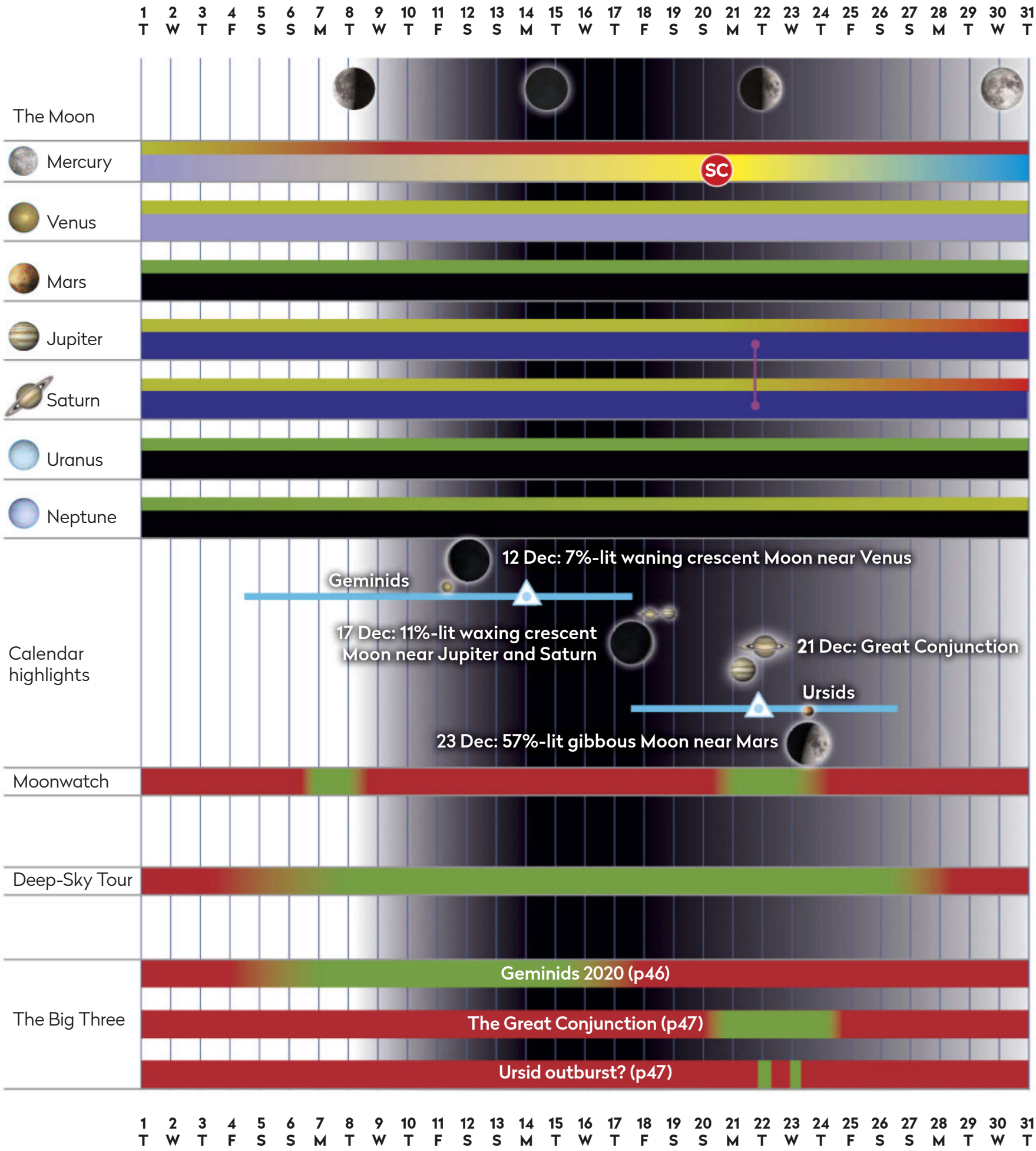
AT A GLANCE

How the Sky Guide events will appear in December



KEY

Observability

Optimal | Poor

Best viewed

Morning twilight | Daytime | Evening twilight | Night

Sky brightness during lunar phases

Dark (first quarter) | Light (full Moon) | Dark (last quarter) | Total darkness (new Moon)

IC Inferior conjunction (Mercury & Venus only)

SC Superior conjunction

OP Planet at opposition

Meteor radiant peak

Planets in conjunction

Full Moon

First quarter

Last quarter

New Moon

CHART BY PETE LAWRENCE

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BBC Sky at Night MAGAZINE

A month with THE MOON

Follow the Moon over the course of a full lunar month and let it be your guide to other beautiful objects in the night sky, as **Scott Levine** explains

What's the first thing you look for in the sky each night? Most of us head straight for the Moon, and with good reason, as many of us got started in astronomy by watching our nearest neighbour. It's an easy target and even beginners can get joy from observing the Moon and learning its phases. All these years later, I still feel that same excitement I felt when I was a child, as I watched its shape change from one night to the next.

While the Moon is certainly wonderful on its own, it can also be our guide to the night sky: a jumping-off point to places all around the Galaxy. Try and make a habit of keeping an eye on it and you'll get a feel for its cycle. From night to night you'll see it move about 13° eastward relative to the much more distant background stars. That's a little more than the width of your fist at arm's length. Watch closely and you might even be able to see the Moon creep along, slowly and silently, over a single night. As it goes, it meets up with new stars, planets and other distant objects, pointing the way so we can learn the skies.

Over the next few pages we'll follow the Moon through a whole lunar month and focus on naked-eye targets that are observable along the way. A lunar month is a full lunar orbit, or a lunation, from one phase back to that same phase again, usually from new Moon back to new; it takes about 29 Earth days to happen.

As it orbits Earth, the Moon travels near the ecliptic, which is the apparent path the Sun takes across the sky. It's a helpful place to look because that line also represents the plane of the Solar System, so all our cosmic neighbours can be found along it. Since the Moon travels close to the ecliptic (its orbit is tilted by about 5°), most of the things we talk about here will also be near that line.

The next new Moon falls on 14 December, so we'll start there. On any night of this lunar month, just look for the date in the pages ahead. Then head out, find the Moon and look up; it's that simple! The Moon rises at different times each day, so there is no specific time that covers all of these entries. Just remember to dress warm, it is winter after all, and if you're reading on a mobile device, remember to switch it to red-light mode to retain your dark-adapted vision.

Let's begin our tour with the Moon as our guide! ▸

More **ONLINE**

For more moongazing tips, lunar features to look out for and guides to lunar science, visit: www.skyatnightmagazine.com/the-moon

For moonrise times and phases delivered to your email inbox, sign up to our e-newsletter: www.skyatnightmagazine.com/newsletter

TOP TIPS

Don't be surprised to see the Moon in the daytime. Travelling all the way around Earth, it spends half its time on Earth's daytime side. A last-quarter moonset against a blue morning sky is a stunning sight!

WILL GATER

Moon charms: get familiar with how the Moon appears at different stages in its lunar month and you'll discover the best times to observe its features

Early phases: new to first quarter

Earthshine: the thin crescent we see after new Moon is when Earth's light shining onto the Moon is at its strongest

14 December It's a new Moon, a phase that occurs when the Moon is between Earth and the Sun, hidden in the Sun's glare and invisible to us. If you're in a long, narrow stretch of the Southern Hemisphere, mostly open ocean and parts of Chile and Argentina, you'll see the Moon slide across the Sun's face and block it out in a solar eclipse! But we don't have eclipses every lunation because the Moon's orbital tilt puts it just above or below the Sun, from our point of view.

15 & 16 December Still in the Sun's glare, the Moon is tough to see, but on the 16th, you may be able to spot a thin waxing crescent just after sunset.

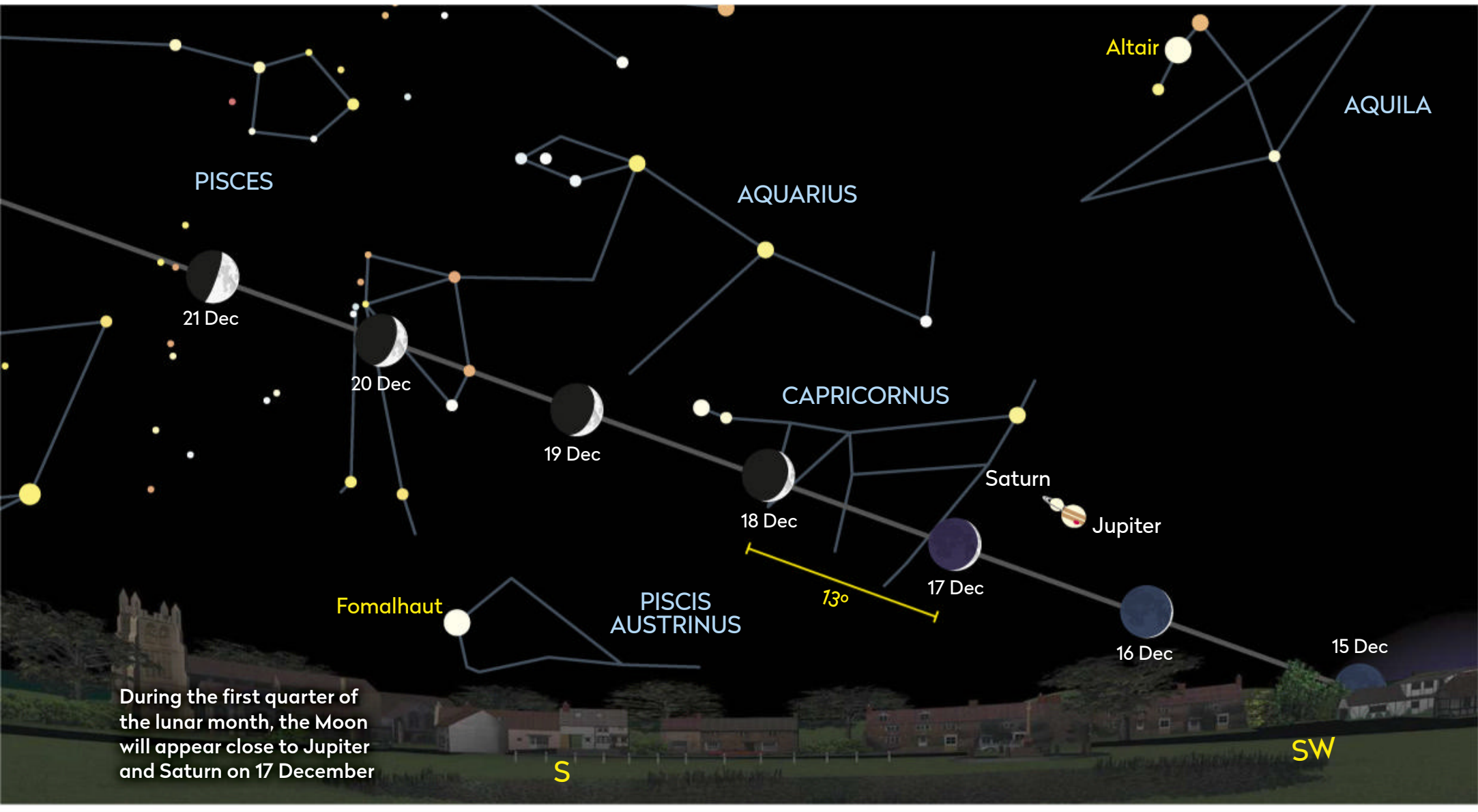
17 December As the Moon pops into the night sky, we see it alongside Jupiter and Saturn, which appear very close (the two planets approach a Great Conjunction on the 21st). In this tiny corner of the sky are the two biggest planets and 162 of our Solar System's moons.

18 December See that dim glow on the Moon's left-hand side? That's Earthshine: sunlight that bounced off Earth, travelled to the Moon, and then bounced back to your eye. As we start the prime, easy-viewing part of the lunar month we've left the giant planets behind. The Moon's now in a long line with Altair (Alpha (α) Aquilae) – which is part of the Summer Triangle asterism – the brightest star in Aquila, high above it and toward the west. Fomalhaut (Alpha (α) Piscis Austrini) is toward the south.

19–21 December On its way to meet Mars, the Moon spends these nights crossing the seemingly empty ocean of sky that gives Fomalhaut its 'loneliest star' nickname. Fomalhaut is the southernmost first magnitude star visible in the Northern Hemisphere, so you may need to hunt for it above the horizon.

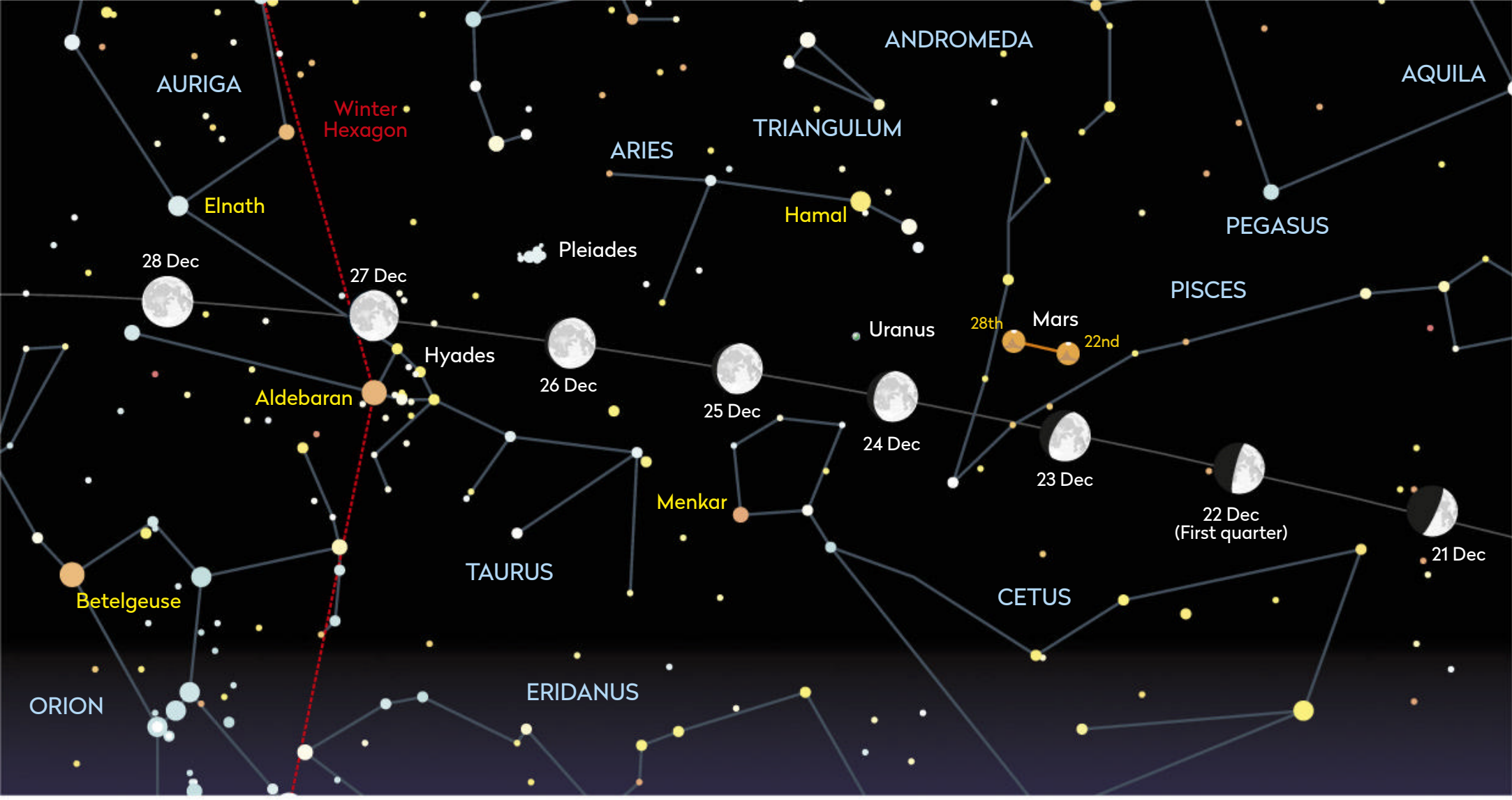
TOP TIPS

Watch as often as you can to get a feel for the Moon's timing and motion.

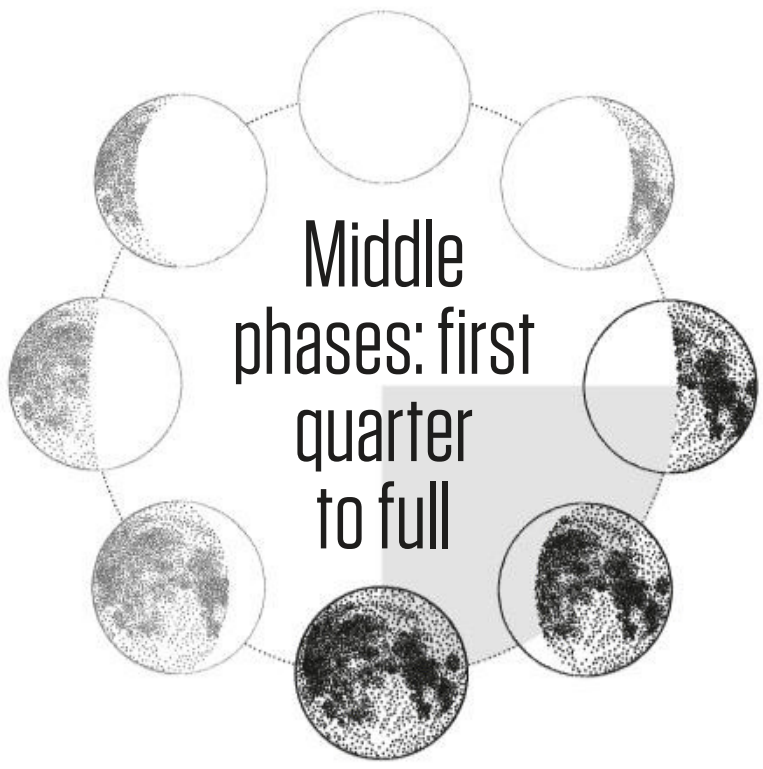


During the first quarter of the lunar month, the Moon will appear close to Jupiter and Saturn on 17 December

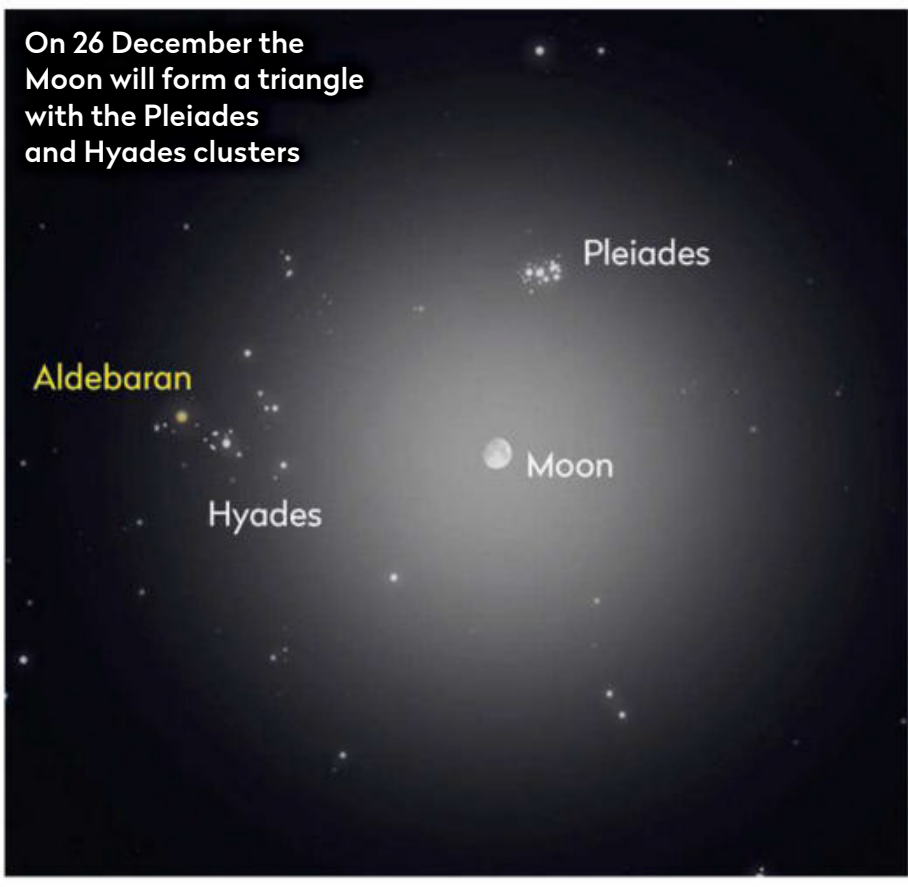
DENCAKE/ISTOCK/GETTY IMAGES, CHARTS BY PETE LAWRENCE, WILL GATER, PETE LAWRENCE



▲ As the Moon heads towards its full phase, it will be visible near Mars before meeting the Winter Hexagon



Middle phases: first quarter to full



On 26 December the Moon will form a triangle with the Pleiades and Hyades clusters

22 December First quarter is when the Moon is off to Earth's left, as seen from the Northern Hemisphere while facing the Sun. It trails after Earth in our orbit, and its right-hand half is illuminated.

23 December We made it to Mars; tonight the Moon points us right towards the Red Planet's festive glow. Notice how the shadows of the hills and mountains on the Moon's waxing gibbous disc stretch toward its darkened part; dawn breaks on more of its face.

24–25 December Merry Christmas! Now a heavy, waxing gibbous, the Moon's shadows are shrinking as the long Sun-Earth-Moon line keeps straightening. With binoculars you may be able to find dusty grey Uranus in the darkness. It's above the Moon to the left at about the same distance as Mars on Christmas Eve, and midway between the two on Christmas night.

26 December The 90%-lit Moon makes a triangle with the dipper-shaped Pleiades and V-shaped Hyades clusters. Reddish Aldebaran (Alpha (α) Tauri) at the top of the 'V' isn't actually part of the Hyades.

27 December The Winter Hexagon is an asterism of six of the night's brightest stars, in six constellations. It's so enormous that it will take the Moon the next four nights to cross it. Clockwise from the Moon, the stars are Aldebaran in Taurus, Rigel (Beta (β) Orionis) at the foot of Orion, Sirius (Alpha (α) Canis Majoris) in Canis Major, Procyon (Alpha (α) Canis Minoris) in Canis Minor, Pollux (Beta (β) Geminorum) in Gemini and the stunning yellow Capella (Alpha (α) Aurigae) in Auriga.

28 December Now nearly full, the Moon is about midway between the giant reddish star Betelgeuse, which forms one of Orion's shoulders, and second magnitude Elnath (Beta (β) Tauri), one of the horns of Taurus, the Bull. The Moon is very bright for the next couple of nights, but that glare adds a certain stark warmth to the night. Elnath is toward the Galactic anticentre. As you look out at that star, imagine your gaze drifting beyond the Milky Way and out into the depths of the Universe. The Galactic centre is back towards the Sun, towards new Moon, nearly opposite where the Moon is now. ►

TOP TIPS

The best time for viewing the Moon is from a few days after its new phase to a few days after full, when it's out of the Sun's glare and up early.

The overnight shift: full to last quarter

A setting full Moon is a beautiful sight just after sunrise on the 30th

29 December Tonight is full Moon! Now we're halfway through the lunar month and the Moon has moved behind Earth. Shadows are flat because the long Sun-Earth-Moon line is straight, running in that order. Full Moons rise around sunset and set around sunrise. Towards the horizon, you might be able to find second magnitude Alhena (Gamma (γ) Geminorum), which forms the foot of Pollux, one of the Twins, while his and Castor's heads are toward the east.

30 December Treat yourself to the sublime sight of a setting full Moon to start your day and then, after your part of Earth has turned away from the Sun, see the Moon rise again, now in a waning gibbous phase between Pollux and Alhena.

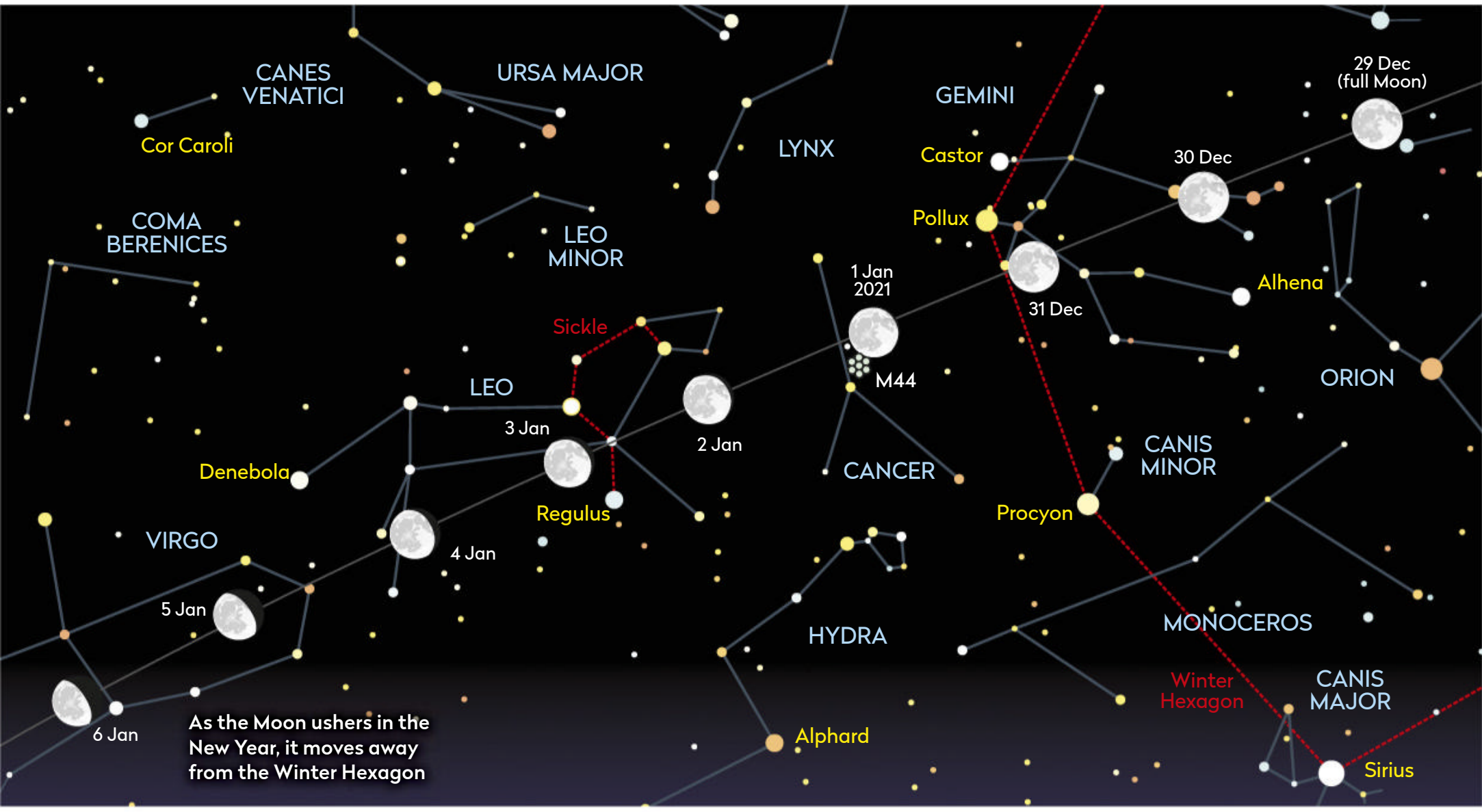
31 December – 1 January 2021 Happy New Year! I think we're all glad to say goodbye to 2020, as the Moon says goodbye to the Winter Hexagon.

2 January Prime Moon-watching ends for now as the Moon rises too late for many of us. If you stay up, you'll see it alongside Regulus (Alpha (α) Leonis), in the constellation of Leo. For tonight, the Moon is part of the Sickle asterism that makes up the Lion's front end.

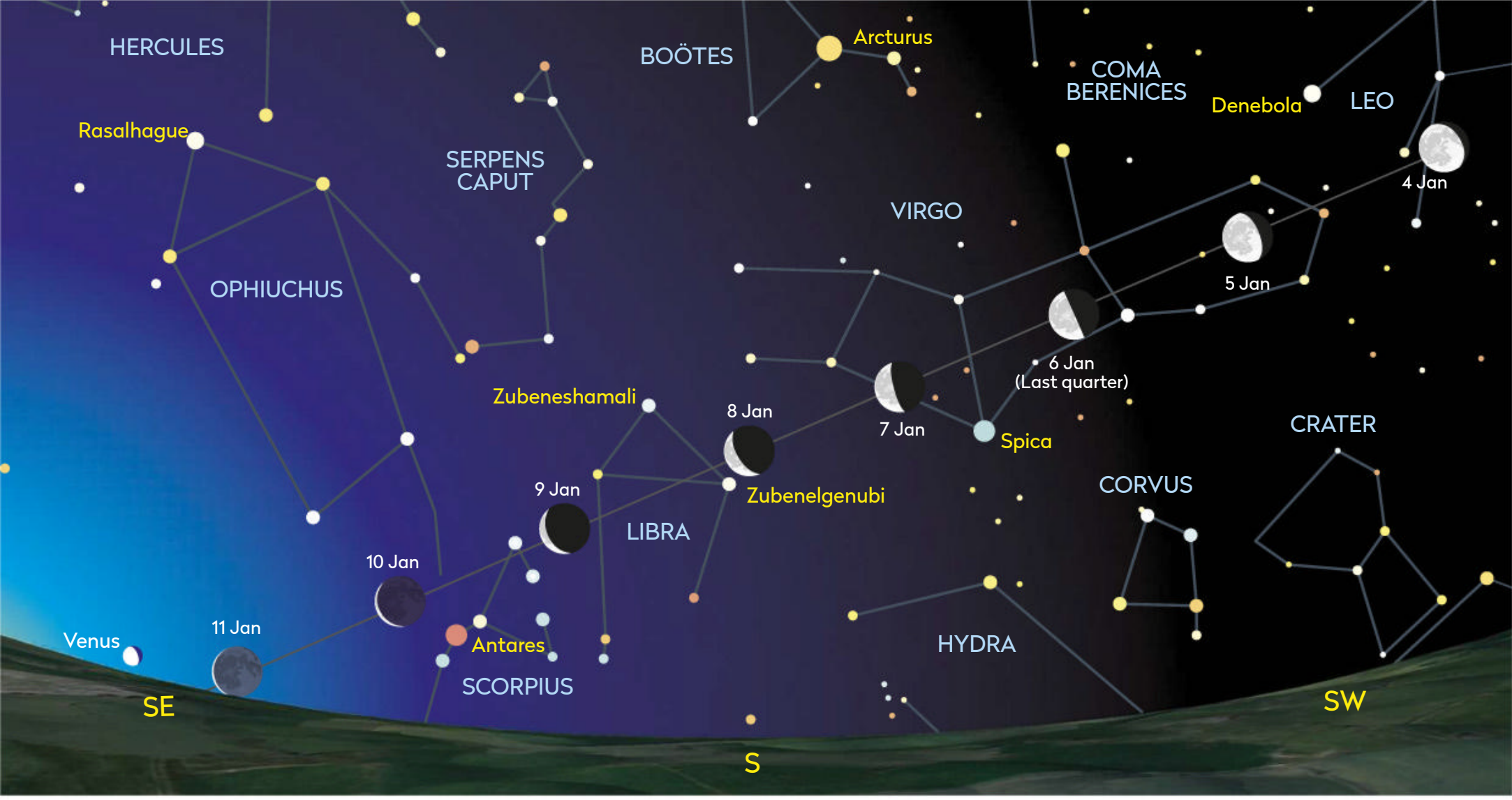
3-5 January The Moon doesn't get higher than 20° above the horizon until around midnight or later now. It crosses under Leo's belly as it goes, and then crosses into the constellation of Virgo, the Virgin.

TOP TIPS

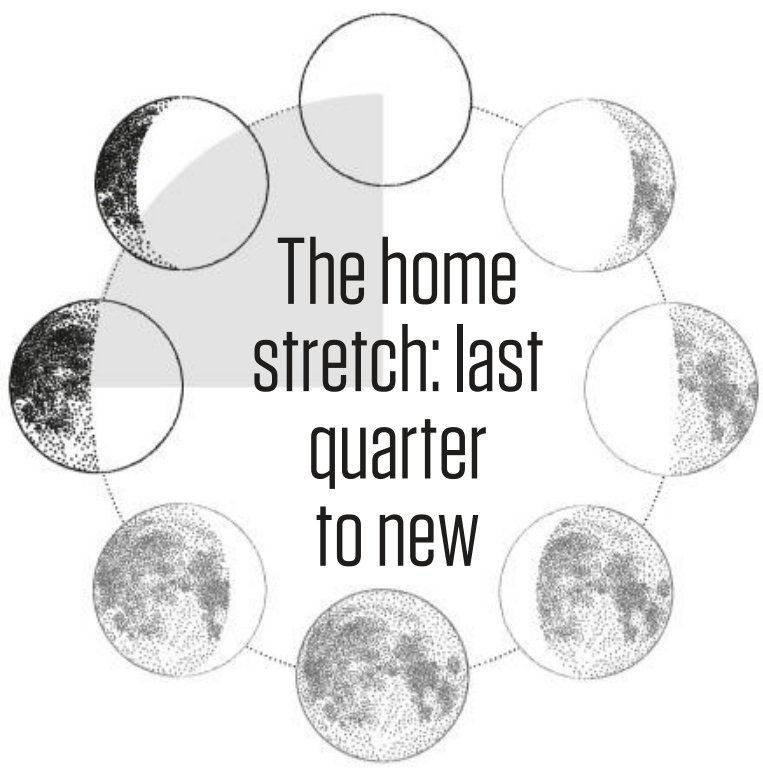
You can see amazing detail with your naked eye; those dark splotches are ancient lava beds.



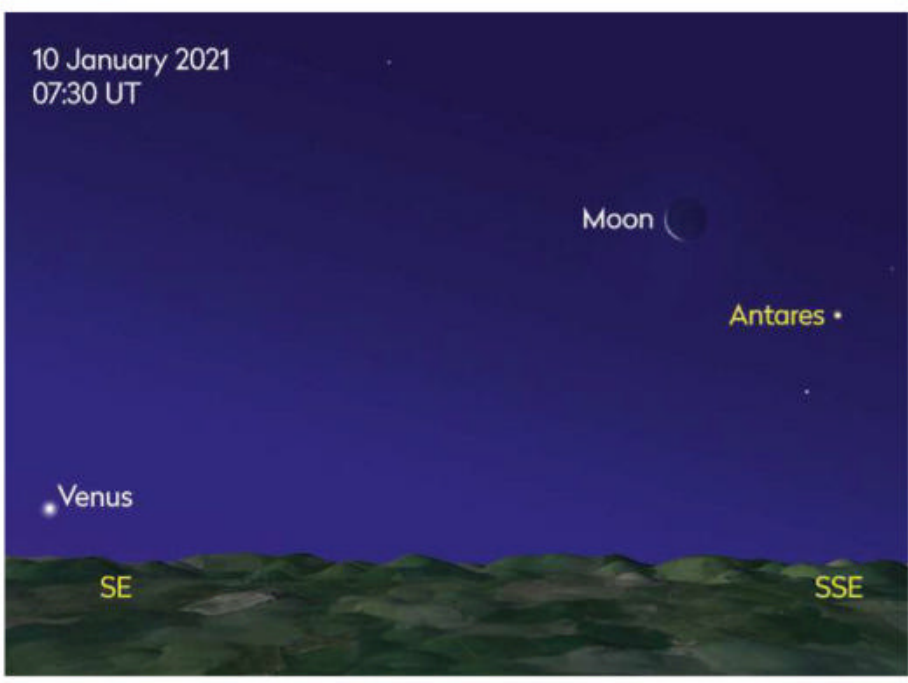
As the Moon ushers in the New Year, it moves away from the Winter Hexagon



▲ In the last quarter of the lunar month, the Moon becomes a morning object



The home stretch: last quarter to new



▲ A simulation of a thin crescent waning Moon near the star Antares, rising before the Sun on 10 January

6 January Last quarter is when the Moon appears to Earth's right, as seen from the Northern Hemisphere while facing the Sun. It's actually ahead of Earth now, leading us along in our orbit. The last quarter Moon rises around midnight, so there's not much to speak of tonight. This is when the Moon becomes a morning object.

7 January In the tiny hours we'll see Spica (Alpha (α) Virginis) just to the Moon's south and Arcturus (Alpha (α) Boötis) to the east. With Regulus from a couple of nights ago, the stars in this part of the sky are a sneak preview of spring. If you're not used to early morning stargazing, take in the quiet and the emptiness around you. I love waning crescents; they're backwards from what you're probably used to; it's a bit unsettling, but they always make me smile.

8–9 January Deeper into the morning we go. When the Moon finally does rise, it's near Libra's flamboyantly named stars Zubenelgenubi (Alpha (α) Librae) and Zubeneschamali (Beta (β) Librae): on one side on the 8th, and the other on the 9th. In a few months, we'll see these in the southern sky where they're like a gateway to summer, with spring's Corvus and Crater to their west, and summer's Scorpius and Sagittarius to the east. See if you can glimpse some more Earthshine on these mornings.

10–11 January The Moon is very difficult to see, rising just a short time before the Sun does. It's a thin crescent just to the east of reddish Antares (Alpha (α) Scorpii) on the 10th. This is your last real chance to see the Moon until it comes out on the other side of the next new Moon. It'll be tough, but the Moon will be west of Venus on the 11th.

12 January This lunation ends with the Moon nearly impossible to see, as it rises just before the Sun. New Moon is tomorrow, and we'll start the cycle all over again. There's no eclipse this time, though.

There's magic in the skies every night, and if you're just starting out, you can always count on the Moon to guide you through the stars and show you the way to some amazing things. We hope you enjoyed this month in the life of the Moon, and hope you'll let us know how it goes!

TOP TIPS

See which phases you like best. I love them all but prefer a couple of days on either side of first quarter.

Scott Levine is a US naked-eye astronomy enthusiast based in New York's Hudson Valley.

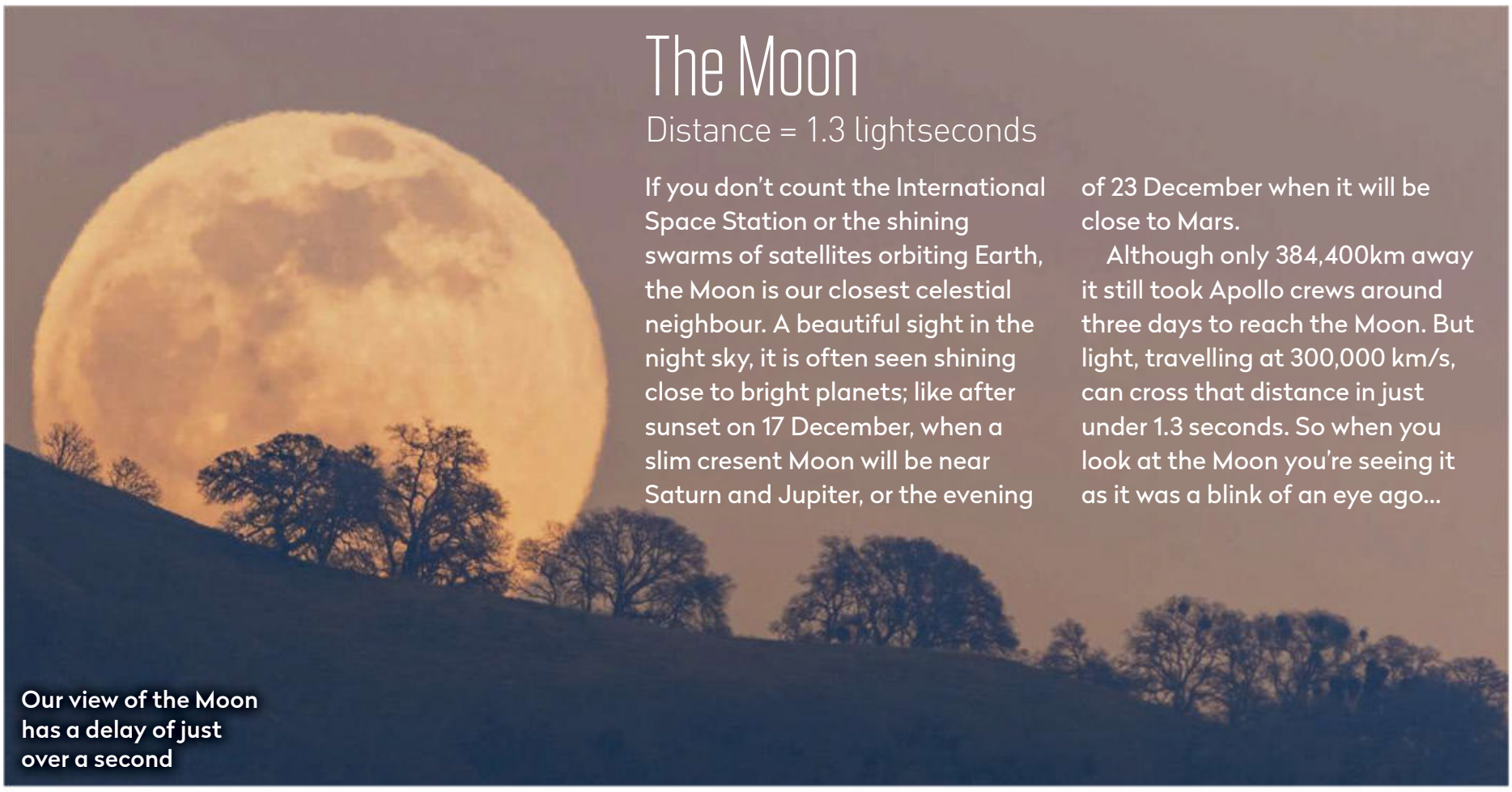
NEAR and FAR

What was happening here on Earth when light left some of the night sky's most stunning sights? **Stuart Atkinson** investigates

Viewing the past: the light from stars can take thousands of years to travel through space, meaning we see them not as they are but as they were

As a child, hiding behind a curtain in the school library, devouring books about space when I should have been outside playing, I was amazed to read that when we look up at the stars we are looking back in time too. The light entering our eyes from these distant objects set off years, decades or millennia earlier. It still fascinates me today knowing that every time we look at something 'up there' we're seeing it as it was in the past.

Science fiction has got it wrong; you don't need a TARDIS or a DeLorean to travel back in time – your own eyes will do just fine. To demonstrate, here we take a temporal tour of objects in the night sky this month, which can be seen from a back garden. Buckle up, where we're going we definitely don't need roads...



The Moon

Distance = 1.3 lightseconds

If you don't count the International Space Station or the shining swarms of satellites orbiting Earth, the Moon is our closest celestial neighbour. A beautiful sight in the night sky, it is often seen shining close to bright planets; like after sunset on 17 December, when a slim cresent Moon will be near Saturn and Jupiter, or the evening of 23 December when it will be close to Mars.

Although only 384,400km away it still took Apollo crews around three days to reach the Moon. But light, travelling at 300,000 km/s, can cross that distance in just under 1.3 seconds. So when you look at the Moon you're seeing it as it was a blink of an eye ago...

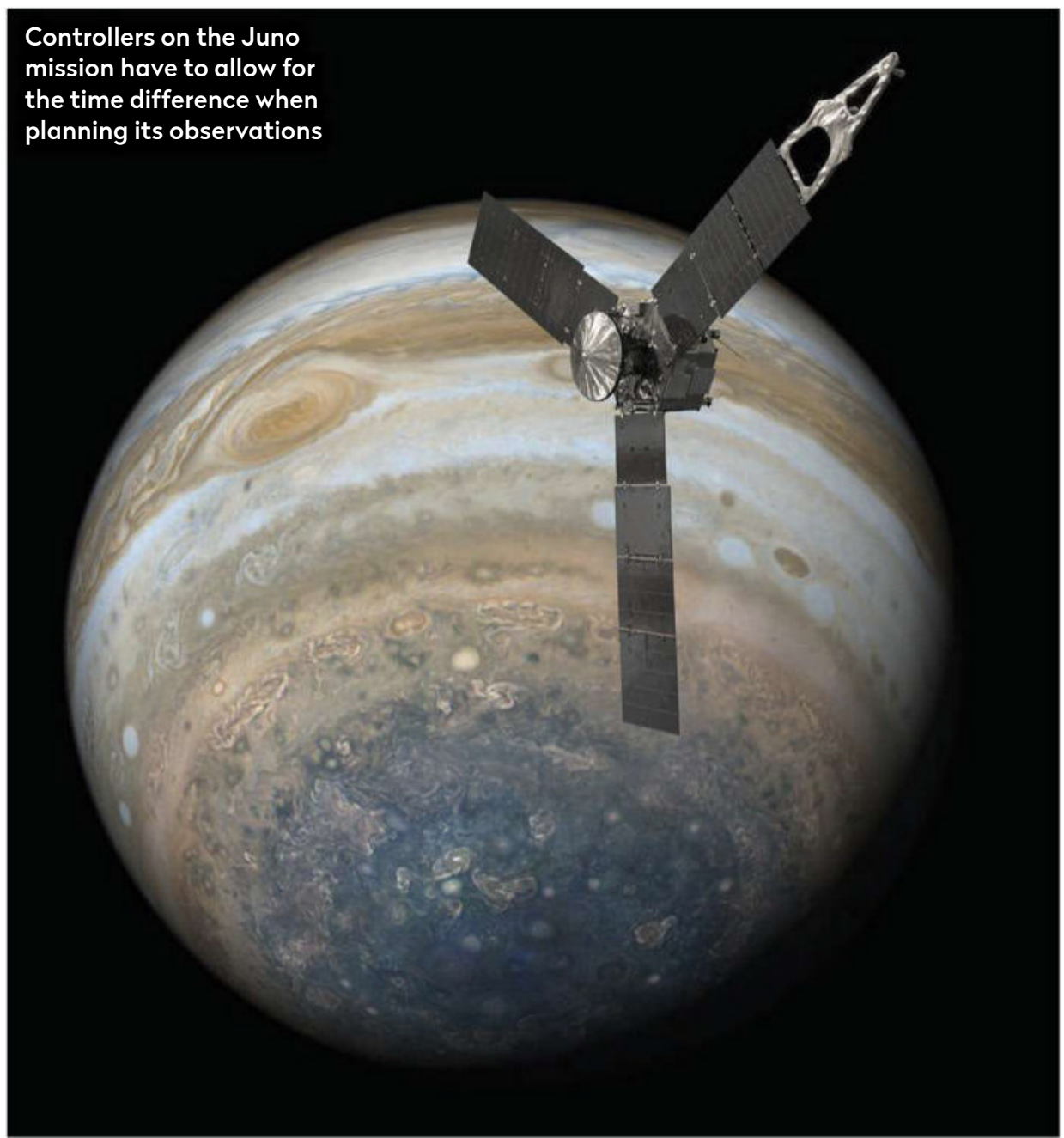
Our view of the Moon has a delay of just over a second

Jupiter

Distance = 48 lightminutes

Heading outward into the Solar System, past Mars and across the asteroid belt, we eventually come to the most massive planet in the Solar System, Jupiter. The gas giant is more than 870 million km from Earth at the moment, and more than five times farther from the Sun than we are. That means that when you look at it this month, shining low in the deepening twilight close to Saturn, you'll be seeing it as it was 48 minutes earlier.

That's not inconvenient for us stargazers, but engineers controlling the Juno space probe, currently orbiting Jupiter and sending back stunning photographs of its swirling cloud bands, do have to take the time delay into account. It means having to plan imaging sequences very carefully and with great accuracy, well in advance. ▸



Controllers on the Juno mission have to allow for the time difference when planning its observations

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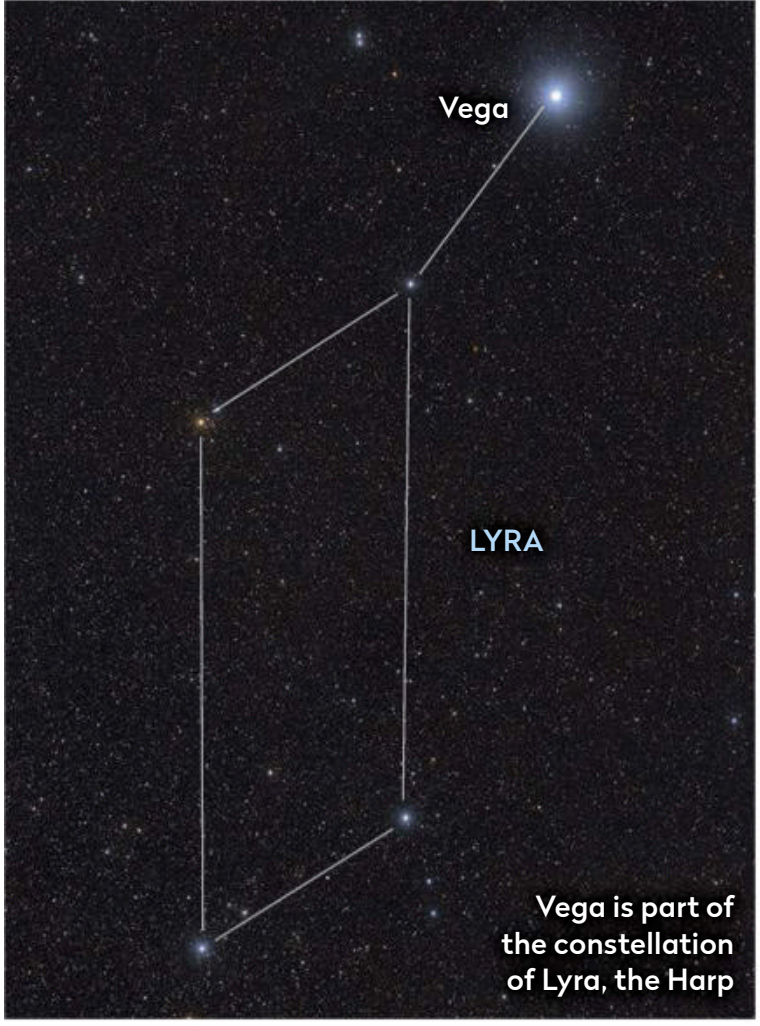
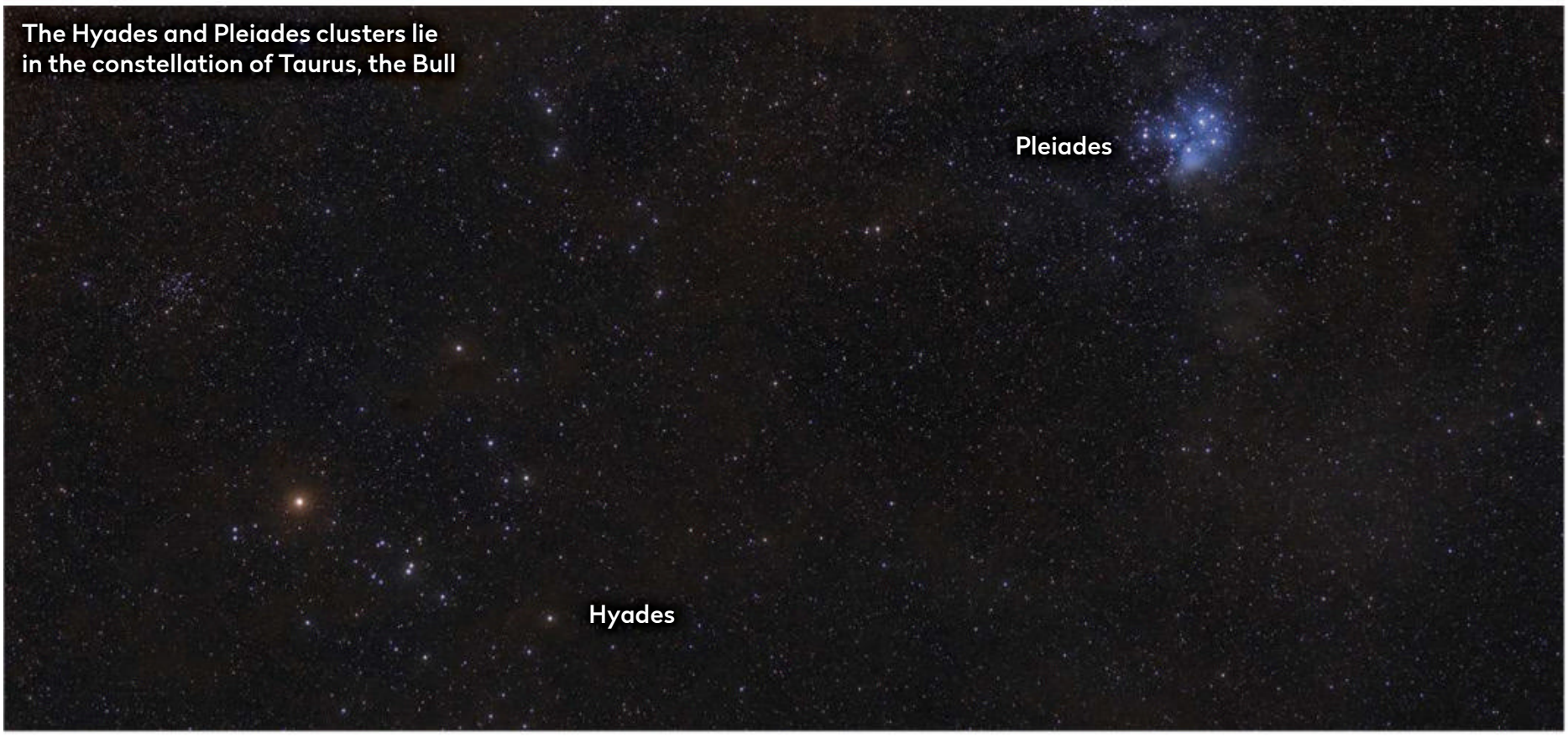


Vega is part of the constellation of Lyra, the Harp

Vega Distance = 25 lightyears


Atlantis and MIR in 1995

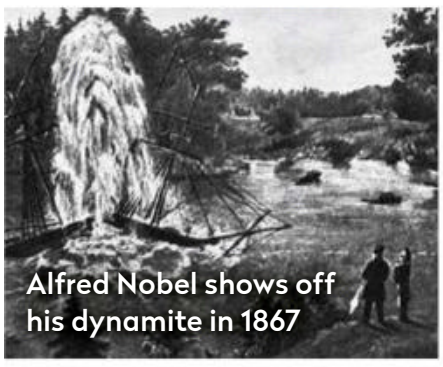
The brightest star in the famous Summer Triangle – still visible this month, just – Vega is the fifth-brightest star in the sky. It's a luminous, rapidly rotating blue-white star and is surrounded by a disc of material thought to be forming planets. Thanks to the wobble, or libration, of Earth as it orbits the Sun, Vega was the Pole Star around 12,000 BC and will be again in 12,000 years' time. As you look at 25 lightyear-distant Vega, perhaps while waiting for Santa on Christmas Eve, you will be seeing light that set off in 1995, the year we witnessed the historic first docking of the Space Shuttle Atlantis with the MIR space station on TV, watched *Apollo 13* at the cinema and heard Oasis singing about a 'Wonderwall' on FM radio.



The Hyades and Pleiades clusters lie in the constellation of Taurus, the Bull

The Hyades star cluster

Distance = 153 lightyears


Alfred Nobel shows off his dynamite in 1867

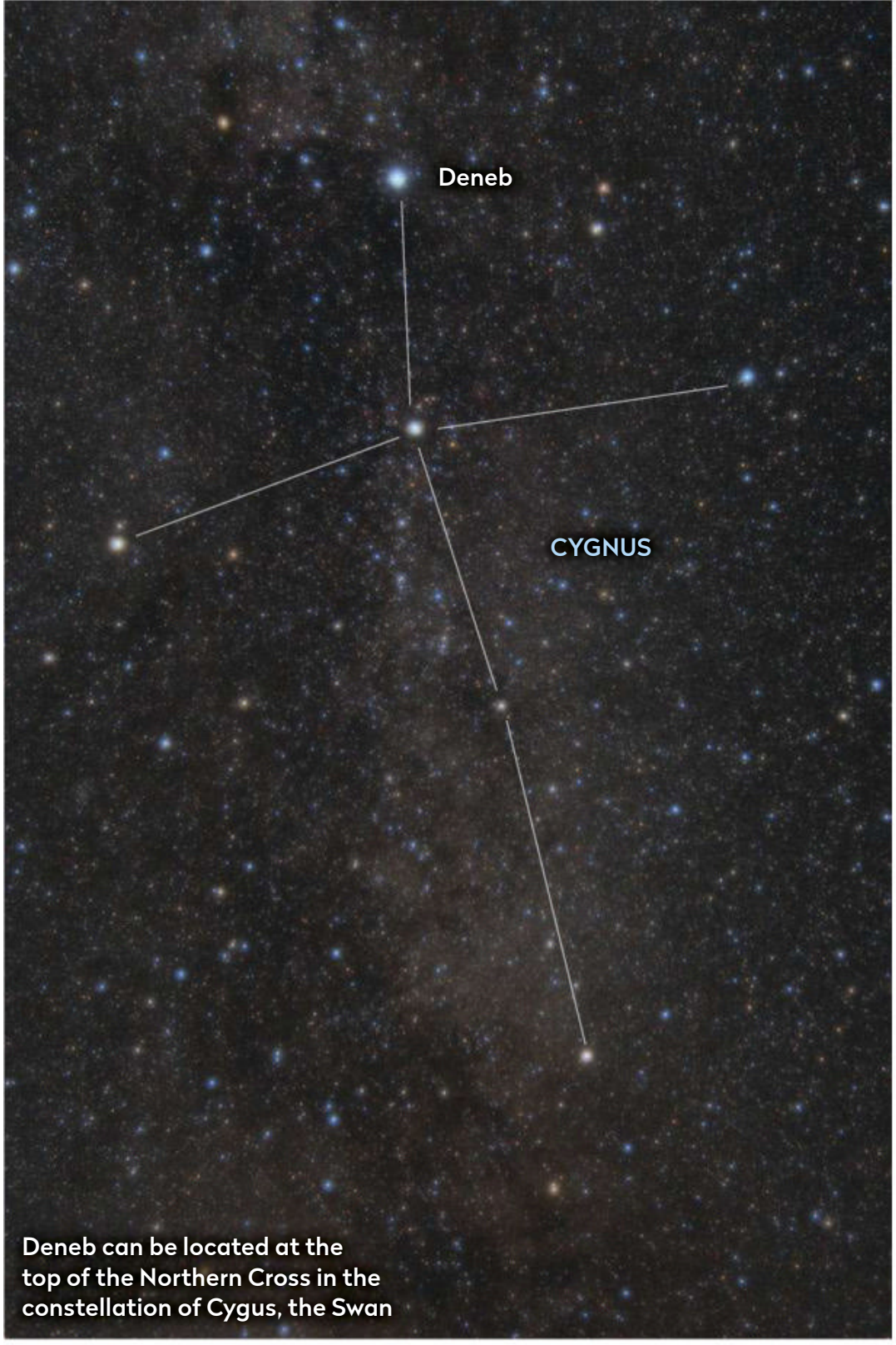
December's night sky is dominated by two star clusters, the Pleiades and the Hyades, both of which lie in the constellation of Taurus. The V-shaped Hyades cluster, which represents the wickedly sharp horns of the Bull, is the nearest open star cluster to us and is a collection of several hundred stars, although the brightest, orange-red Aldebaran, is closer than the others and just a line-of-sight effect. When looking at the Hyades you are seeing light that set off roughly 153 years ago, in 1867, when Queen Victoria was on the throne, Alfred Nobel first demonstrated the power of dynamite and Johann Strauss's *The Blue Danube* had its first public performance – 101 years before being used so perfectly in the space station docking sequence of *2001: A Space Odyssey*.

The Pleiades star cluster

Distance = 440 lightyears


The Golden Hind returns to Plymouth in 1580

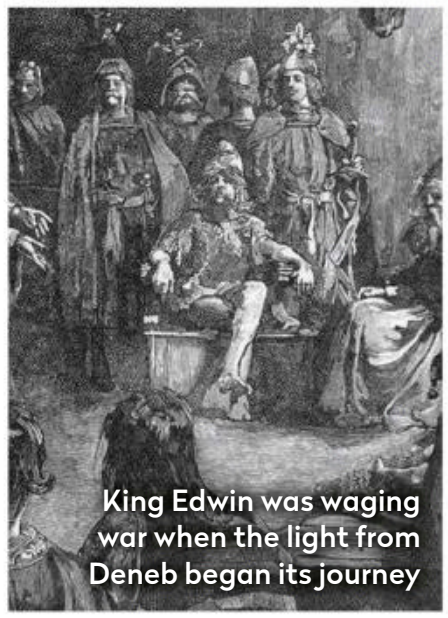
More than twice as far away as the neighbouring Hyades, the Pleiades has to be the most famous star cluster in the whole sky. A tight group of more than a thousand stars, M45, or the Seven Sisters, is a stunning sight in binoculars and telescopes alike and is the closest Messier object to Earth. At 440 lightyears away, the sparkling Pleiadean starlight we see on frosty autumn and winter evenings set off on its journey across space around the year 1580. At this time Elizabeth I was on the English throne, Francis Drake sailed back into Plymouth harbour on board the Golden Hind after his second epic voyage of circumnavigation, and *Greensleeves* was being performed for the first time.



Deneb can be located at the top of the Northern Cross in the constellation of Cygus, the Swan

Deneb

Distance = 1,400 lightyears


King Edwin was waging war when the light from Deneb began its journey

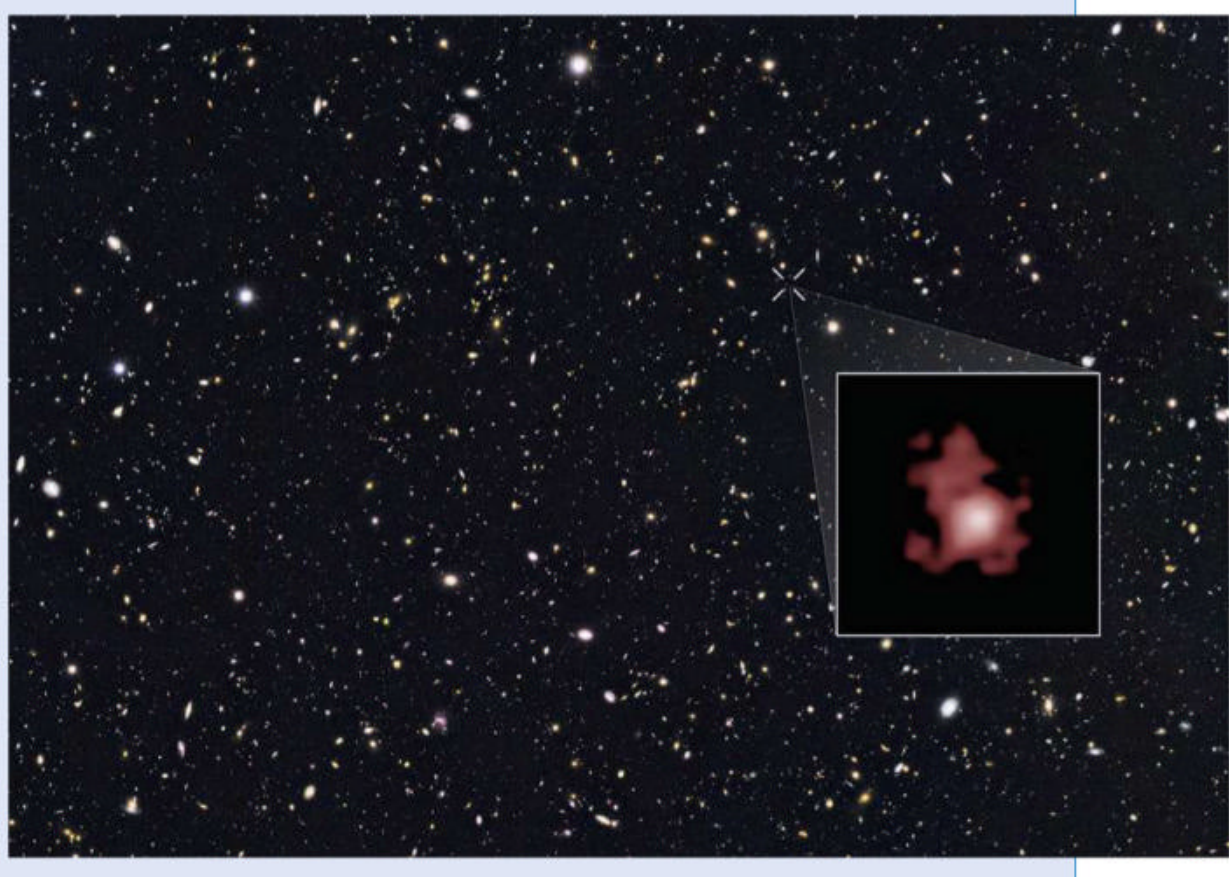
Shining at the head of the Northern Cross, mag. +1.25 Deneb is the 19th brightest star in the sky and is 1,400 lightyears away, based on recent measurements. Not just popular with astronomers, it also features in many sci-fi stories; it has been visited several times in *Star Trek*, and is famous as being the home star system of the Silver Surfer. A bloated supergiant star between 55,000 and 196,000 times more luminous than our own Sun, the icy blue-white light reaching us this December set off on its journey to us some 1,400 years ago, in the year 620 AD. This was a time of conflict in Dark-Age Britain, with the Angles, led by King Edwin of Northumbria, fighting with tribes across the north of England. Elsewhere, the Tang dynasty was rising in China and the Mayan empire was starting to lose its stronghold in what is Mexico today. ▸

How far back in time can we look?

High-powered professional telescopes can almost see back to the dawn of the Universe

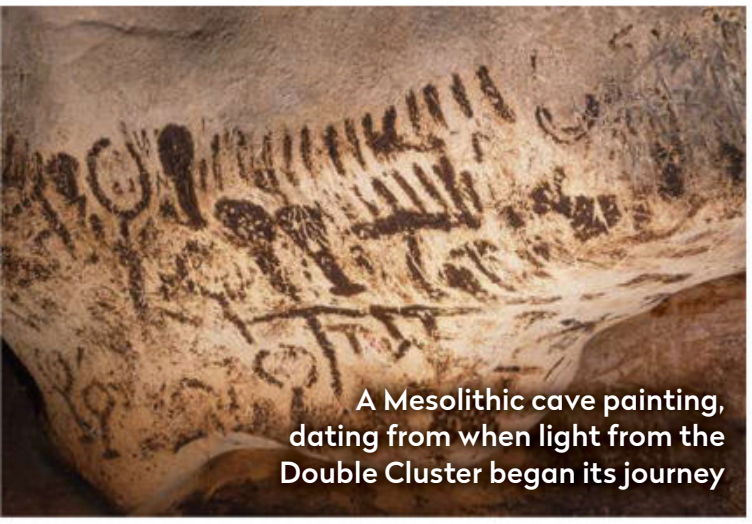
With enormous modern telescopes and sensitive detectors, professional astronomers can see far beyond what most back garden telescopes are capable of. As far as our own Solar System is concerned, one of the farthest objects observed so far is a 500km-wide asteroid, 2018VG18. Also known as Farout, it is over 120 times further from the Sun than Earth, or three times further away than dwarf planet Pluto. If you were standing on Farout's dark, pink icy surface, Earth would be a mag. +6.8 'star' hugging close to the Sun and Jupiter would shine at barely mag. +5.0. If a space probe ever reaches Farout it will take 17 hours for its radio signals and images to reach Earth.

As for the most distant object ever seen in the Universe, the current record holder is a galaxy – GN-z11. Located in Ursa Major, GN-z11 is a young galaxy barely 1/25th the size of our own, and it is so far away that when its faint light is observed by astronomers they are looking back in time more than 13 billion years, to just 400 million years after the Big Bang. It is expected that when it finally launches, the James Webb Space Telescope will be able to look even further back in time and observe events that happened long ago in galaxies far, far away...


▲ The position of GN-z11, the most distant galaxy discovered so far, as shown in a deep-sky Hubble Space Telescope survey from 2016

The Double Cluster

Distance = 7,500 lightyears



A Mesolithic cave painting, dating from when light from the Double Cluster began its journey

The famous Double Cluster in Perseus

Look roughly halfway between the upside down 'Y' of Perseus and the distinctive 'W' of Cassiopeia and you'll see a misty patch, quite obvious to the naked eye and which binoculars resolve into a pair of pretty star clusters shining close together.

Unsurprisingly, this is known as 'the Double Cluster' and the two objects, NGC 869 and NGC 884, are both around 7,500 lightyears away. The light from their stars set off just at the tail end of Europe's Mesolithic period, when the Ice Age was ending and when melting glaciers resulted in rising sea levels, cutting Britain off from continental Europe. Meanwhile, humans were just beginning to learn how to farm and domesticate animals.

The Hercules Cluster, M13, looks like a small comet through binoculars

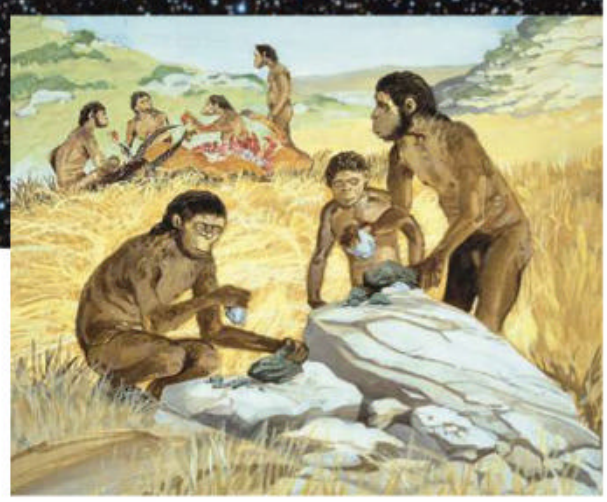
M13

Distance = 23,000 lightyears

Scan the sky down to the lower right of Vega and you'll see a small asterism – the 'Keystone' of Hercules – a bit like a rectangle squashed in at the bottom. On its right side, not far from the top corner star, is a tiny, faint smudge of light. This is M13, the Hercules Cluster, a globular star cluster containing many hundreds of thousands of stars, which looks like a small comet in binoculars and a mottled, smoky ball in telescopes. Large aperture instruments can resolve individual stars on the cluster's edge, and beautiful trails and tendrils of stars within it. A staggering 23,000 lightyears away, the faint light now reaching us from this cluster set off during the last Ice Age.

Mammoths were walking Earth and the Ice Age was underway when light left M13

The Andromeda Galaxy, M31, is the Milky Way's galactic neighbour



► Homo habilis was using stone tools when light from M31 began its journey to Earth

M31

Distance = 2.5 million lightyears

Finally, we reach the last stop on our temporal tour of the December sky, and where better to end it than with the most distant object visible to the naked eye – M31, the Andromeda Galaxy. Visible to the eye on a dark, Moon-free night as an extended smudge between Cassiopeia and the Great Square of Pegasus, M31 is a vast spiral galaxy, perhaps twice the size of our own Milky Way, and more than 2.5 million lightyears from it. When we look at M31 we are not just staring across a gulf of space, but far back in time too, to when our Homo habilis ancestors were using sophisticated stone tools in East Africa, and the UK was buried under sheets of ice.

Stuart Atkinson is a lifelong amateur astronomer, public outreach educator and author of nine books on astronomy and spaceflight

Imaging Andromeda

Capturing the 2.5 million year-old light of M31 is a great project for new astrophotographers

M31 is famously the most distant thing visible to the naked eye, but that's only true if you have good eyesight, a dark sky with no light pollution and you know where to look for it. Luckily, even if you have none of those things it's quite easy to photograph this beautiful spiral galaxy – all you need is a DSLR on a sturdy tripod. You don't even need a tracker or stacking software.

To take a portrait of the Andromeda Galaxy, M31, fit either your wide-angle lens or standard 50mm lens onto your DSLR, mount it on a sturdy tripod, open the lens to its widest aperture and then focus in sharply on a light on the horizon. With its ISO set to 800, aim your camera at the sky roughly halfway between the 'W' of Cassiopeia and the closest corner of the Great Square of Pegasus. Set a time delay of 10 seconds and then begin the exposure, preferably using a cable release to reduce shaking.

Your picture will show you M31 as a small lens-shaped smudge. Ok, it might not rival those images taken by Hubble or through a telescope, but it will have recorded the combined light of trillions of stars, capturing starlight that took an amazing 2.5 million years to reach your camera.

Set your DSLR up on a steady tripod and train it on the faint smudge of M31 in the sky

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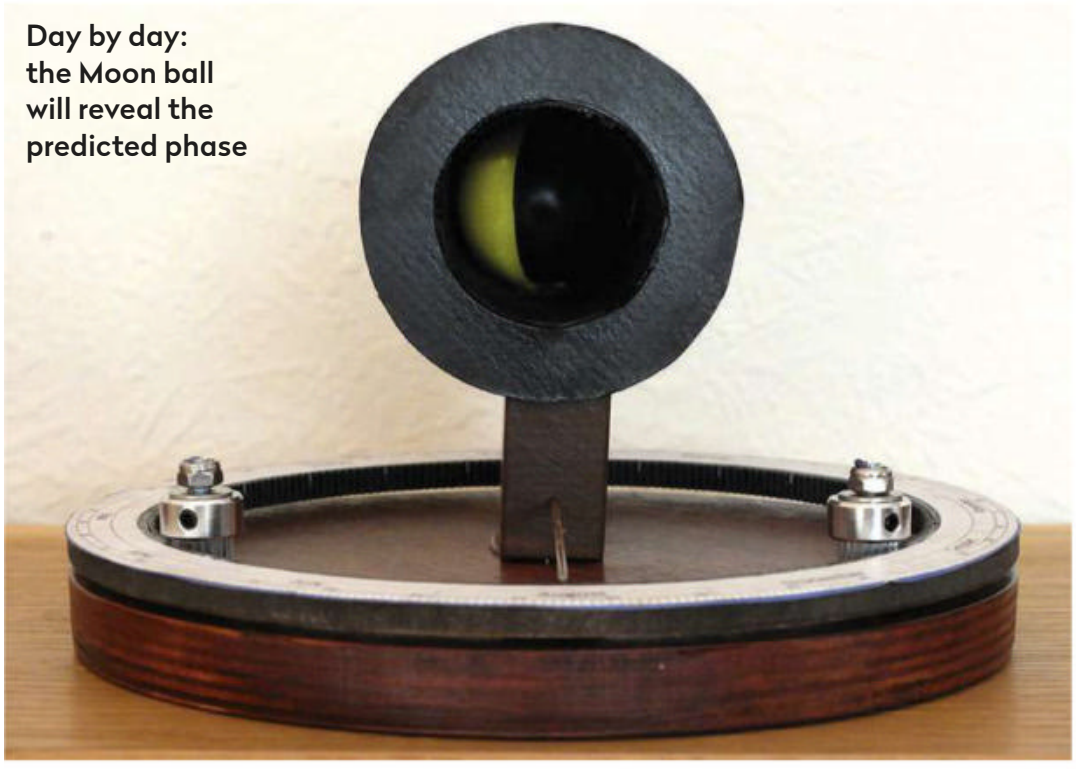
DIY ASTRONOMY

Make a lunar phase calculator

Create an instrument to show the phase of the Moon on any given date

More **ONLINE**

Download diagrams and photos for this project. See page 5 for details.



Day by day: the Moon ball will reveal the predicted phase

This month's project is a mechanical instrument that 'calculates' and displays the predicted phase of the Moon for any chosen day of the year. Our design uses a GT2 timing belt and pulleys – commonly used in printers and readily available online – to generate the movement, and we have provided downloadable plans and extra photos and diagrams, so the build should be straightforward.

To use the calculator (pictured, above), you turn the year ring so that the wire pointer aligns with the date you are interested in. When you then look into the viewing tube you will see that the painted Moon ball has turned to reveal the predicted phase.

Phases of the Moon

The real Moon's phases take 29.53 days to complete their cycle from new Moon through the waxing phases to full Moon, then the waning phases back to new Moon. This means there are 12.36 phases in one year of 365 days. The year ring of our calculator has 247 teeth on its inner circumference, driving the 20-tooth Moon pulley, and this ratio of 12.35 to 1 is very close to the real 'phase-to-year' ratio. The slight difference might require a small adjustment if you fast-forward several years ahead, but once you know (or observe) the date of a new or full Moon, it is easy to re-calibrate the instrument.

The trickiest part of the build is producing the smooth circular hole inside the year ring. If you have a router with a compass attachment this isn't too hard, but sanding by hand after cutting with a coping saw requires some care. We devised a simple jig to hold our board after cutting out the approximate inside shape. The jig can be held in a vice or clamped to a bench so that the board revolves about its centre. You gently turn the board while a small sanding drum, fitted into an electric drill – held or clamped so the sander just touches the inside of the hole – smooths the surface. We have added a diagram and photo of this to our downloads section. We found it easy to make small adjustments to achieve the calculated internal diameter of 158.6mm, so that a section of belt with 247 teeth fitted perfectly.

One of the pulleys, turned by the belt, is attached to the Moon ball. The other two pulleys turn freely and are only used to guide the year ring and keep it in contact with the Moon pulley. It's best to drill the holes in the base for the two guide pulleys after fitting the Moon pulley, as you may need to make small corrections to ensure they will all turn smoothly.

We hope you enjoy making and using your lunar phase calculator; you may even wish to customise it by adding some decoration or using more sophisticated materials. The calculator is great for planning observations, such as when you need a moonless night. As well as its practical applications it's an interesting talking point and looks good enough to display.

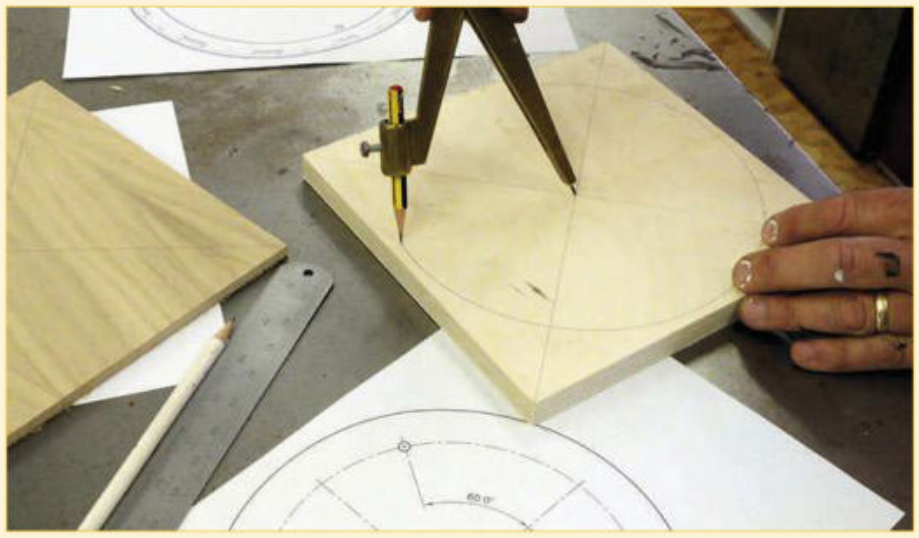
Mark Parrish is a bespoke designer. See more of his work on his website: **buttondesign.co.uk**

What you'll need

- A ruler, compasses, pencil, coping saw, drill and range of bits, and a small sanding drum attachment
- A sheet of 6mm MDF or plywood (200 x 200mm), a piece of board for the base, softwood offcuts for the sanding jig and tube stand, a table tennis ball for the Moon, a cardboard tube, plus a thin, stiff wire for the pointer
- Sundries include four M5 screws (40–50mm long), two Nylock nuts and five washers, three GT2 drive pulleys (with 20 teeth), a length of GT2 6mm-wide timing belt cut to 247-teeth (500mm long) and glue
- For the finish you'll need wood stain, matt black spray and yellow paint

ALL PICTURES: MARK PARRISH

Step by step

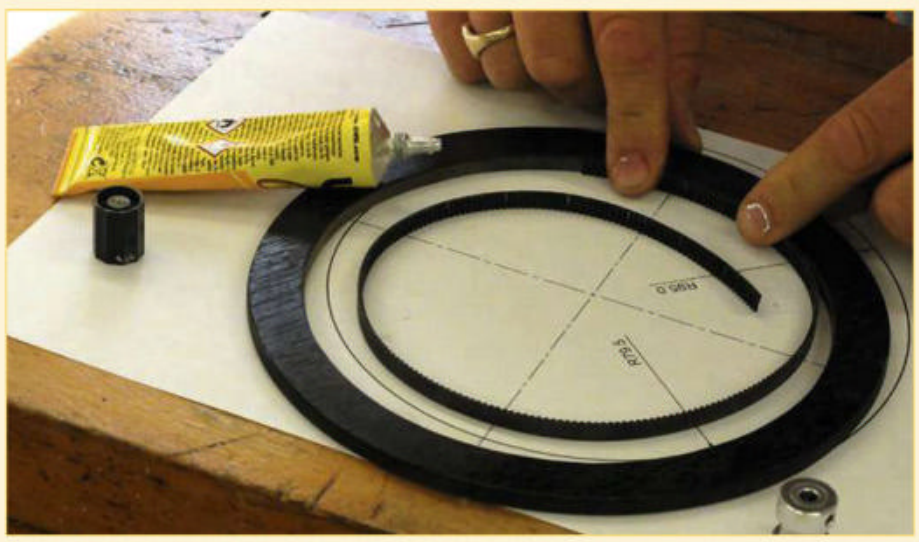


Step 1

Use the downloadable, printable drawings and mark out the base and year ring. Use the point of a compass to mark the centre positions of the three pulleys on the base; these will be confirmed before drilling. Next, cut out the base and inside of the year ring.

Step 2

By temporarily screwing the year ring board to a simple jig (held in a vice), you can turn it so that a small sanding drum in a hand drill can smooth the inner circumference. You can increase the diameter until the 247-tooth belt fits perfectly inside.



Step 3

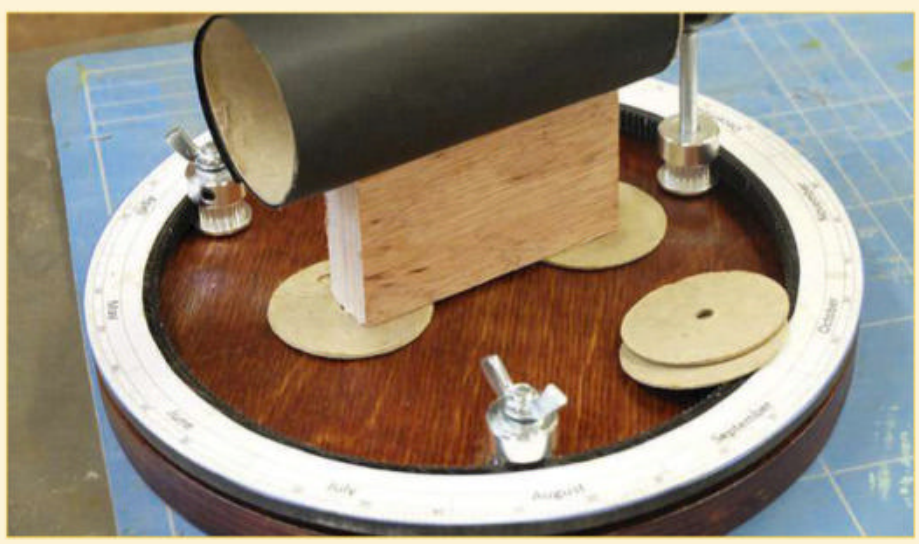
After finishing and painting the year ring, glue the drive belt to the inner edge. We also treated our plywood base to some wood stain and varnish. While the glue is drying, cut out the card parts and paint them and the cardboard viewing tube matt black.

Step 4

Paint most of the table-tennis ball yellow, then, using masking tape to mask the yellow hemisphere half, paint the rest matt black. Next, glue an M5 screw to the Moon ball so that when rotated, the Moon phases are shown.

Step 5

Loosely position the pulleys and year ring on the base. One at a time, spot through with the drill, then drill a neat hole and temporarily fix each pulley with a screw. Before drilling the third pulley make sure the fit is not too tight or the ring might bind.



Step 6

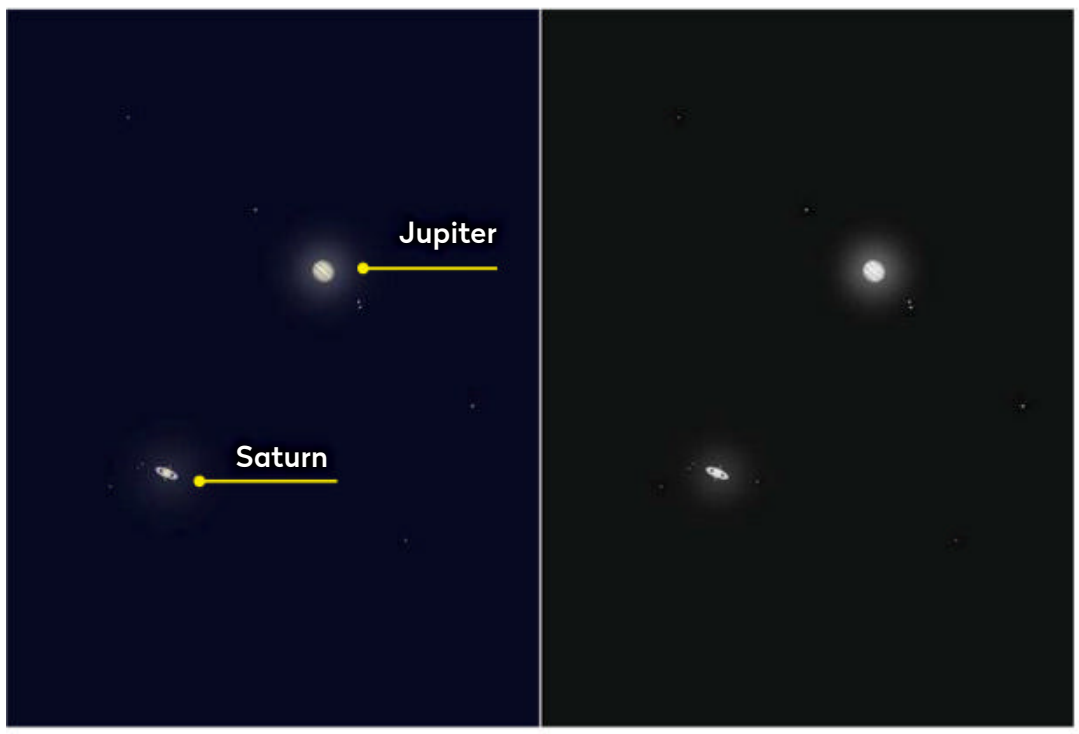
Add calendar dates to the year ring and assemble the moving parts. Use packing to work out the tube's height and make a stand from a softwood offcut and paint it black. Drill a hole in the stand's front to add a wire pointer (see main picture, left) and finish assembly.

Take the perfect astrophoto with our step-by-step guide

ASTROPHOTOGRAPHY CAPTURE

Photograph the Great Conjunction

Capture Saturn and Jupiter in one image thanks to a unique event that hasn't occured since 1623



ALL PICTURES: PETE LAWRENCE

Saturn and Jupiter reach their Great Conjunction on 21 December, when both planets will appear separated by just 6 arcminutes, the closest they've appeared together since July 1623. If the weather plays ball, this event will offer a chance to catch both planets as discs in a single image.

A bit of planning will pay off however, because even though 6 arcminutes is fairly easy to catch using a planetary camera, it's best to image in such a way that the 6-arcminute separation fits optimally inside the camera's imaging frame, meaning the apparent size of each planet will be maximised for the view.

Achieving the correct imaging scale is normally done by using an optical amplifier, a device that adjusts your telescope's effective focal length and therefore its imaging scale. Examples of optical amplifiers include Barlow lenses, Powermates and focal reducers. Barlows and Powermates have powers which are greater than 1. For example, a 2x Barlow lens will double your scope's effective focal length and image scale. A focal reducer is similar but it has a power less than 1, so a 0.5x focal reducer halves your telescope's effective focal length, giving you a wider view.

▲ Great expectations: try and frame Jupiter and Saturn together, and make several captures of the grouping, like the one shown in these simulated images

Pete Lawrence is an expert astro imager and a presenter on *The Sky at Night*

A quick way to determine the sort of image scale you will need is to use your imaging setup to image the Moon; its apparent diameter is around 30 arcminutes, so a separation of 6-arcminutes is one-fifth the apparent diameter of the Moon.

Formulaic approach

A more mathematical approach is to use the formula:

FOV (field of view) in arcminutes = imaging chip width in mm x 3,460 ÷ telescope focal length in mm

Bearing in mind we need a bit of tolerance to capture both planets' extended families of moons, a long dimension of, say, 8 arcminutes will allow both planets and some moons to be caught. Rearranging the formula, we can calculate the required focal length as:

Telescope focal length in mm = imaging chip width in mm x 3,460 ÷ FOV in arcminutes

So, if your camera's sensor has a long dimension of 11mm, the desired telescope focal length in millimetres is 11.0 x 3,460 ÷ 8 = 4,757mm, or 4.75 metres.

If you were using a telescope with an 800mm focal length you'd need to use an optical amplifier with a power of 5.94x to achieve the calculated optimal value. However, as such a precise optical amplifier power isn't available, using a 5x Powermate would suffice. Another option is a 2.5x Barlow coupled with a 2x Barlow, which might get a similar result, but may reduce the image quality a bit.

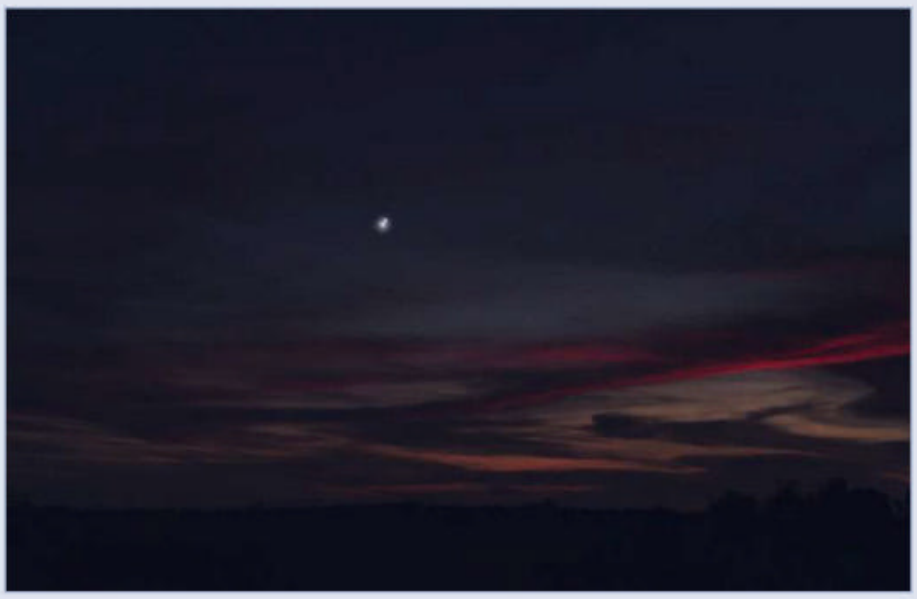
The key is to avoid exceeding the calculated value, as this may create a scale that doesn't permit both planets to appear on chip at the same time.

Recommended equipment: 200mm or larger telescope, high frame rate planetary camera, optical amplifier, ADC for colour cameras, red or luminance filter for mono cameras

▸ *Read more about the Great Conjunction on page 29*

✉ Send your images to:
gallery@skyatnightmagazine.com

Step by step

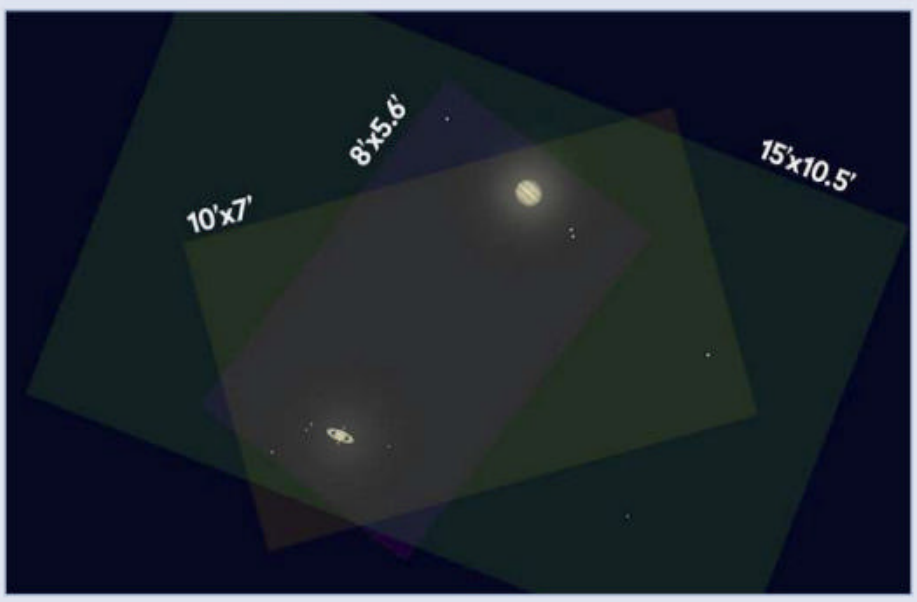


STEP 1

It pays to plan ahead; this is a simulation of the Great Conjunction at closest approach when it's visible from the UK, late afternoon on 21 December. Imaging the planets with a low image scale, eg using a smartphone, will result in two close dots, but a scope will help to boost the image scale so you can see both planets as discs.

STEP 2

Calculate your required focal length as: *CW x 3,460 ÷ FOV*, where CW is your chip's width in mm and FOV is the desired field of view in arcminutes. Once you've calculated the best focal length to use, aim to achieve this by using an optical amplifier. Don't worry about absolute precision here, just avoid going too far over what you need.

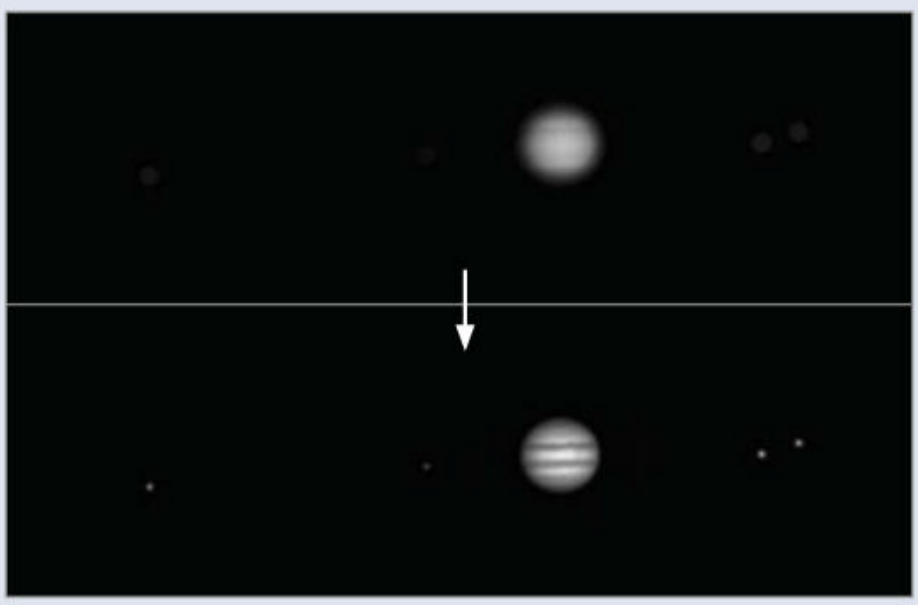


STEP 3

If you just want both planets and their inner moons, a field of view rectangle measuring 8 arcminutes on the long side is ideal; 10 arcminutes creates more space but may still struggle with the 7'08" separation between Europa and Ganymede. A 15 arcminutes long-side field of view will catch it all, with the two brightest field stars.

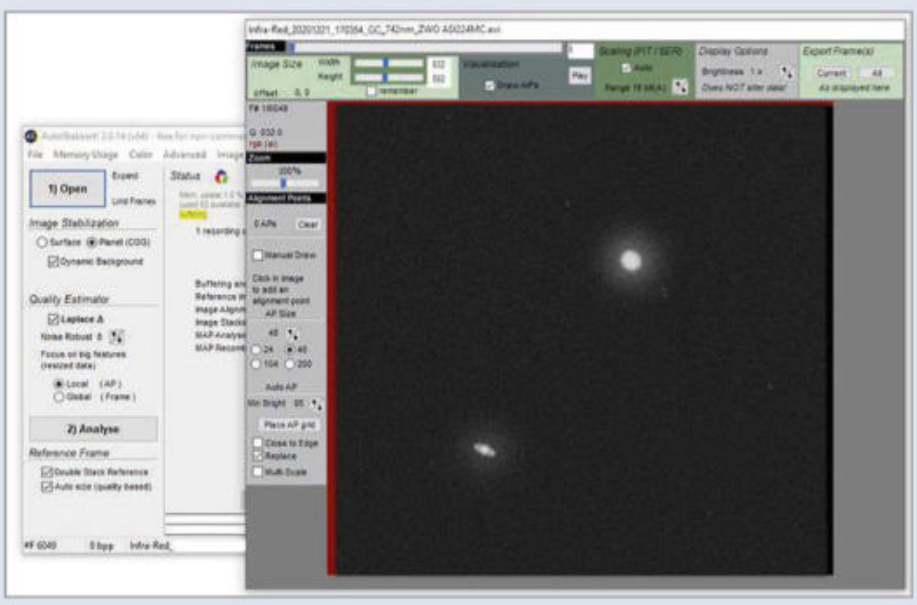
STEP 4

A planetary (high frame rate) camera will overcome issues of low altitude seeing affecting the Great Conjunction; a colour camera (above, top) will need an Atmospheric Dispersion Corrector (ADC) to reduce colour fringing, while a mono camera (above) using an IR pass filter will give the crispest, albeit monochrome, view.



STEP 5

Set everything up and get the planets in frame. If you're using a high image scale and things are tight, rotate the camera so both planets are on the field of view diagonal. Depending how tight your view actually is, you may lose some of the moons here. Once correctly orientated, tighten everything up and focus carefully.



STEP 6

Set the frame rate high for this, all the time keeping an eye on gamma correction and keep it as low as feasible. Aim to collect 500 to 1,000 frames, limiting capture time to around a minute. Make several captures, refocusing in between for safety. Process the result in a registration-stacking program like AutoStakkert 3.

Expert processing tips to enhance your astrophotos

ASTROPHOTOGRAPHY PROCESSING

How to stack DSLR images of the Moon

Create a crisper lunar image by stacking in AutoStakkert! and removing unwanted noise

▲ **The stacked image of the partial eclipse of the Moon from 10 January 2020**

The biggest enemy of the astrophotographer is noise, the unwanted artefacts that appear in images. We often hear about how deep-sky images can be stacked to improve the signal-to-noise ratio (SNR) – where the 'signal' represents the real features in an image we want to keep – but it can also be a problem when we are imaging our nearest neighbour, the Moon. With a DSLR, noise will still be present even at lower ISO settings and this can spoil the appearance of a lunar image (see example images, right).

Fortunately, there are ways to reduce the amount of noise present so that the image looks cleaner and sharper. Just like in deep-sky imaging this process involves stacking several images to produce a combined one. As more images are stacked, the signal is enhanced and stands out more. Noise, on the other hand, being random in each image, becomes less noticeable. In this article, we'll look at how the stacking process can be performed on a lunar image with the freeware AutoStakkert!, which can be downloaded from **www.autostakkert.com**.

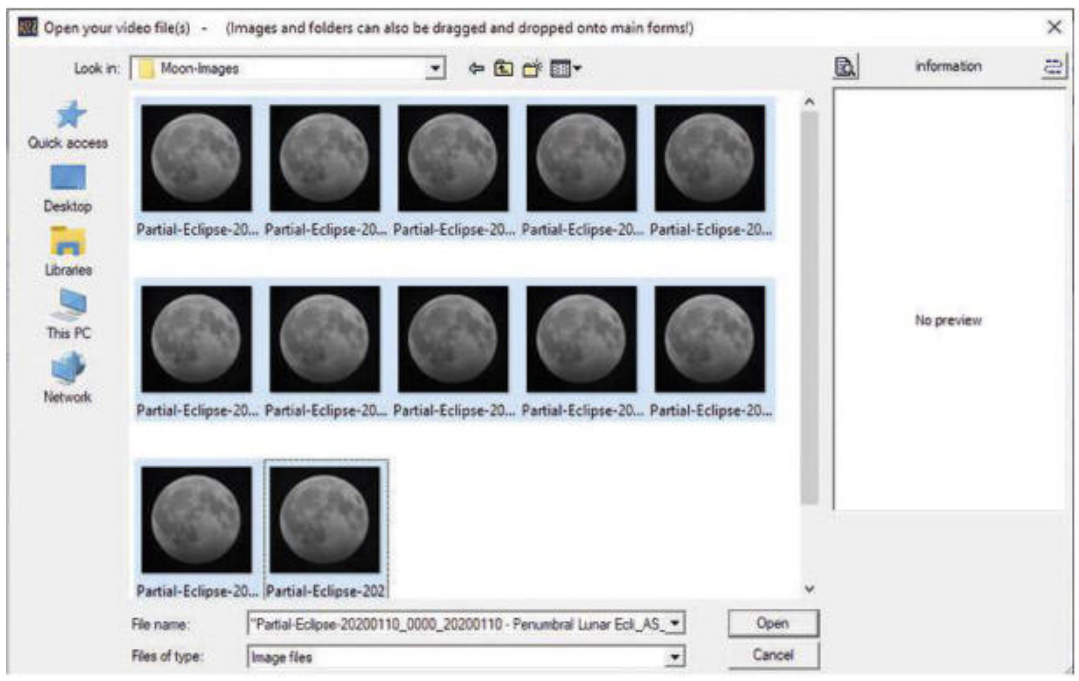
To begin, use the lowest ISO setting your camera has, such as ISO 100, to take an image of the Moon. Adjust the exposure settings to ensure that the histogram peak is near or just left of centre. Once you are happy with the captured image, take several identical images, one after another. If your camera takes RAW images, you will need to convert them to TIFF or PNG files before stacking, as AutoStakkert! cannot stack RAW images. We also recommend that you avoid stacking high-resolution JPEGs, as these are compressed and will not produce the best final images.

Get stacking

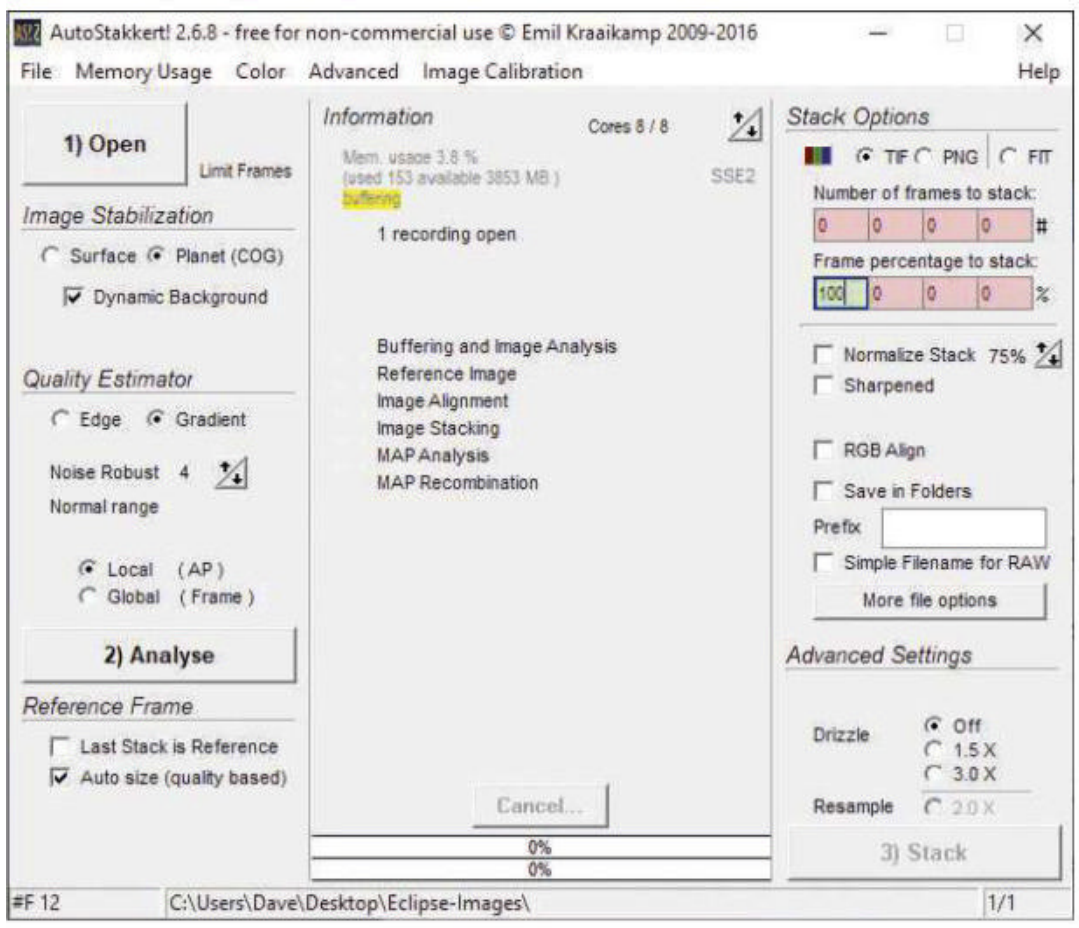
Open the AutoStakkert! software and check that the latest version is installed, which can handle stacking DSLR images. The program opens in two separate windows: one contains the control panel, the other the image panel. Once the software is running, click the '1) Open' button in the control panel and then browse to the folder that contains the images that need stacking. At the bottom of the window, use the drop-down menu to select images.

▲ **Keeping the noise down: a comparison of an image before and after stacking**

ALL PICTURES: DAVE EAGLE



▲ **Screenshot 1: selecting images to be stacked in AutoStakkert!**



▲ **Screenshot 2: prepare your control panel settings to stack images**

Select all the images and click 'Open' (see Screenshot 1, above). Our example uses images taken during the partial lunar eclipse on 10 January 2020. One of the images will now be visible within the image window. If the image cannot be viewed properly, there is a 'Zoom' slider towards the top left of the image panel. Move this to the left to make the image look smaller to fit the window (this doesn't affect the image). At the top of the image panel there is a 'Frames' slider button; by scrolling backwards and forwards you can review each loaded image to check it for quality. If any images are of inferior quality, re-load the other images, leaving those images out. Once you're happy that the images are of a quality suitable for stacking, return to the control panel.

Options to consider

The following stacking options are a good place to start, but you can make changes as you progress to suit the images your camera produces. To begin, use the following settings as a guide. First, save your images as TIFF files before you stack. Next, in the control panel (see Screenshot 2, left) under 'Stack Options' set the 'Frame percentage to stack' at 100% and untick 'Save in Folders' – to avoid having to scroll through folders to find your images. Make sure the 'Drizzle' option is off, because the software crashes if this is used on large DSLR images. Now click '2) Analyse' and AutoStakkert! will look at each image; once it has finished a green tick will appear beside 'Buffering and Image Analysis', with the time taken to perform the action.

Next, go to the image window (see Screenshot 3, above) and look on the left-hand side under 'AP Size' to select one of the sizes; for a DSLR this is usually 200. Finally, click the 'Place AP' grid button and a number of overlapping green squares will appear over the image. These are the Alignment Points (APs) that AutoStakkert! uses to align each image.

Finally, go back to the control panel window and click '3) Stack'; a series of progress bars will indicate the software is now stacking and more green ticks will appear against the different processes, until the stacking routine is complete.

The stacked image should have been automatically saved in the same folder as the images used, ready for any final image tweaking and processing using RegiStax or your preferred image-processing program.

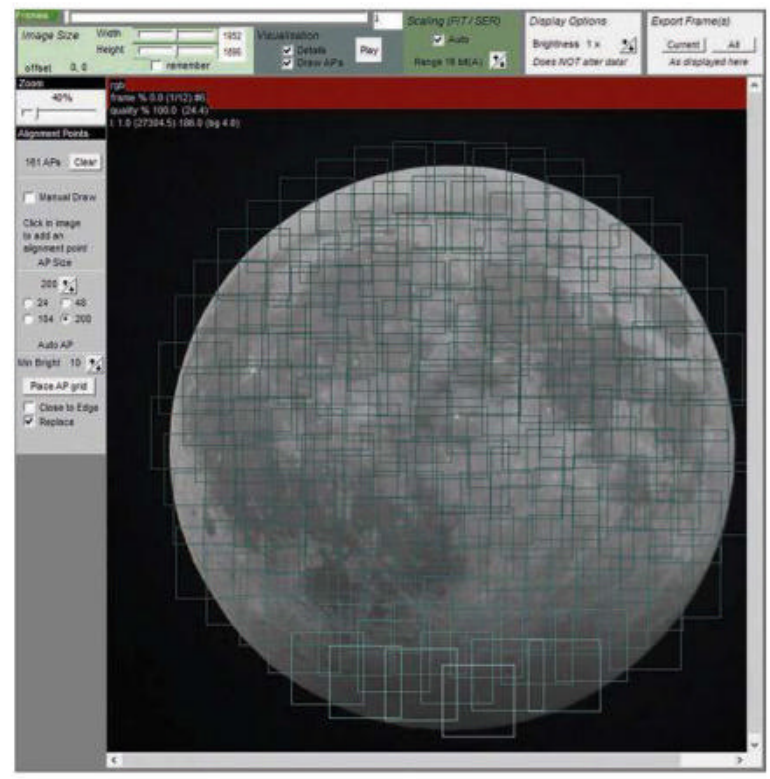
Dave Eagle is an astronomer, astrophotographer, planetarium operator and writer

3 QUICK TIPS

1. Use a low ISO setting and ensure images are correctly exposed so as not to over-expose brighter parts of The Moon.

2. Always stack the sharpest images possible; a mirror-up function will reduce camera shake.

3. Pre-crop the blank sky surrounding the Moon from full-format images before stacking to reduce image file sizes.



▲ **Screenshot 3: set your Alignment Point (AP) sizes in the AutoStakkert! image window**

Your best photos submitted to the magazine this month

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△ Ced 214 Nebula

Daniel Zoliro, Chouteau, Oklahoma, USA, 21–26 August 2020

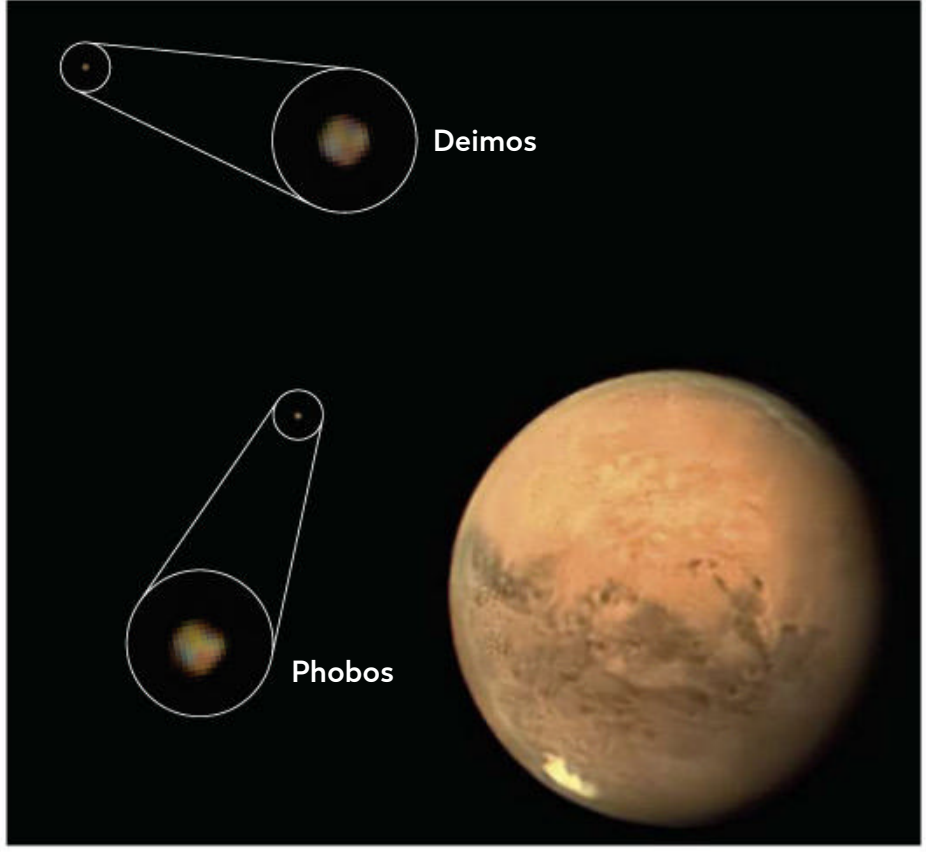
PHOTO OF THE MONTH

Daniel says: "Ced 214 is a beautiful narrowband target that you don't see imaged very often. With several clear nights in a row, I wanted this to be my longest integration project to date – 16 hours [imaging time] in total. I should have taken more OIII (Oxygen-III) data – it made combining the channels a little challenging – but I was able to make it work."

Equipment: ZWO ASI 1600MM Pro camera, Astro-Tech AT115EDT refractor, Sky-Watcher EQ6-R Pro mount **Exposure:** Ha 26x 300", 77x 180", OIII 106x 180", SII 95x 180" **Software:** PixInsight, Photoshop, StarNet++

Daniel's top tips: "I think that producing a great image comes down to three things: 1) good data – refine your capture skills and don't be afraid to throw out bad subs; 2) integration time – it's exciting to process that single hour of data, but several hours makes processing so much easier and will make your images much cleaner; and 3) better processing – put some serious time into your processing skills. It will pay off.

This hobby can be extremely frustrating, but also very rewarding if you're persistent and learn from your mistakes. One last thing: get a good equatorial mount!"



◁ Mars, Phobos and Deimos

Harvey Scoot, Finchingfield, Essex, 14 September 2020

Harvey says: "This is a composite of two separate captures: an over-exposed image of the moons and an image of Mars itself. The image of the moons was taken with autoguiding and using 30-second exposures. Although the seeing was pretty good, the transparency was very variable, so I'm pleased with how it turned out, all things considered."

Equipment: ZWO ASI 462MC one-shot colour camera, Celestron EdgeHD 14-inch Schmidt-Cassegrain, Mesu-Mount 200 **Exposure:** 60 x 30" **Software:** FireCapture, RegiStax, AutoStakkert!, Astra Image, GIMP

Cycling to the Moon ▷

Susan Snow, Cleeve Hill, Gloucestershire, 27 September 2020

Susan says: "On this evening I had taken a couple of shots of the Moon rising when I saw the cyclist approaching."

Equipment: Canon 77D DSLR, Orion ShortTube 80 refractor, Orion AutoTracker mount **Exposure:** ISO 200 f/5, 1/320" **Software:** Canon Digital Photo Professional

◁ The Cygnus Wall

Matthew Baker, Ashbourne, Derbyshire, 18-25 September 2020

Matthew says: "I made the error of misaligning my framing between sessions as I had to clean some dust, and that caused me to only focus on the Cygnus Wall rather than the entire North America Nebula. But it was a blessing in disguise, I'm really happy with the result."

Equipment: ZWO ASI 1600MM Pro camera, TS-Optics 90mm apo refractor, Sky-Watcher HEQ5-Pro mount **Exposure:** Ha 30x 300", OIII 44x 300" **Software:** PixInsight

The Milky Way over Sicily ▷

Dario Giannobile, Punta Bianca, Sicily, 27 June 2020

Dario says: "To make this shot, I used **www.lightpollutionmap.info** to find a location in Sicily that had a dark sky on the horizon. Getting there involved a rough road, and to align the Milky Way I had to ford a stretch of sea to reach the rock under the hut."

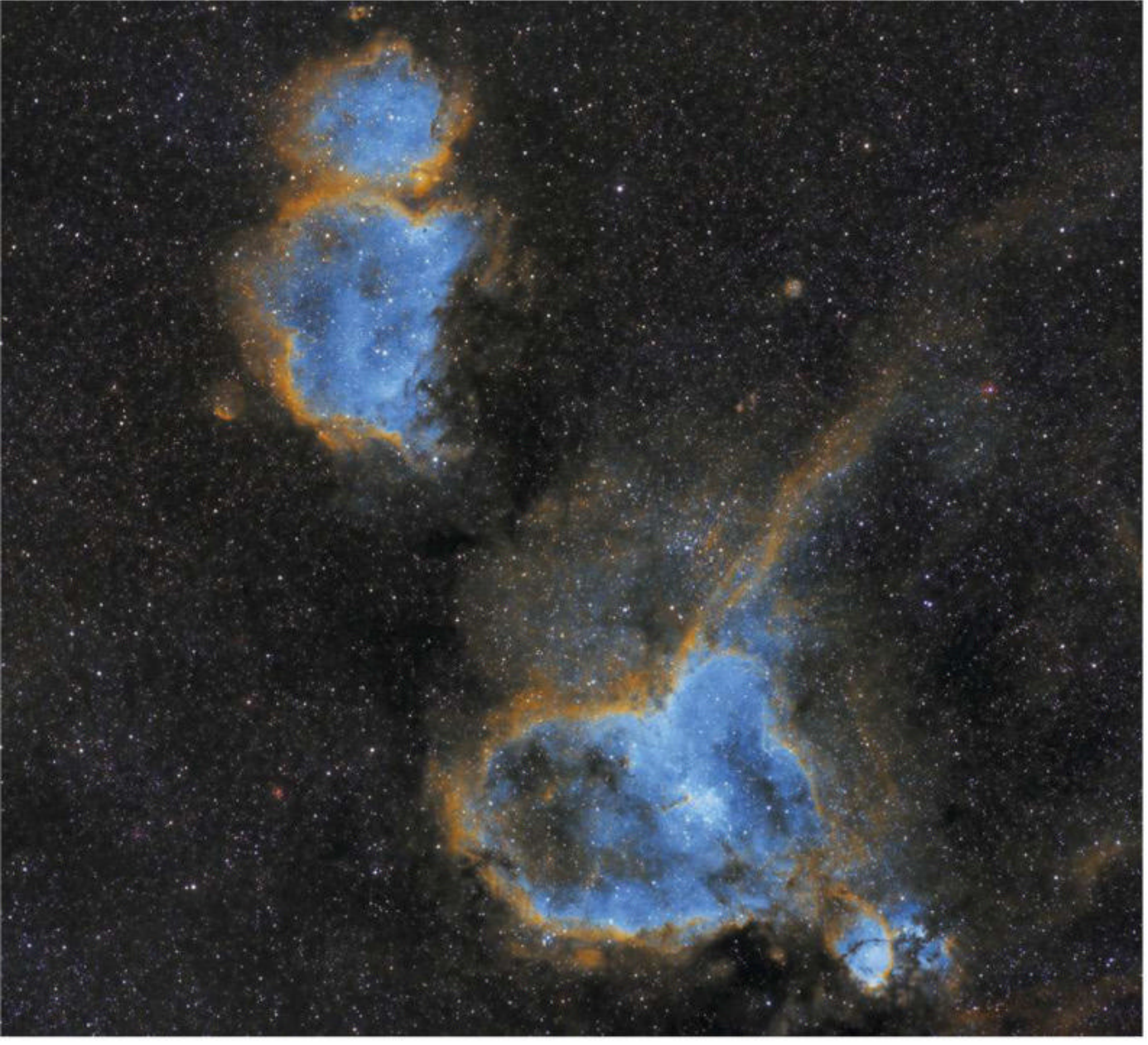
Equipment: Canon 6D DSLR, Sigma 20mm lens, Manfrotto tripod **Exposure:** ISO 800 f/2, 1200" **Software:** Photoshop

▽ NGC 5367 and CG12

Nicolas Rolland, El Sauce Observatory, Chile, August 2020

Nicolas says: "Cometary Globule 12 [CG12] is rarely imaged. It's associated with NGC 5367, which reflects light from two blue stars."

Equipment: SBIG STXL-11002 camera, PlaneWave 17" CDK astrograph, Paramount ME mount **Exposure:** L 23x 1200", R 15x 1200", G 15 x 1200", B 16x 1200" **Software:** CCDstack, PixInsight, Photoshop



◁ Heart and Soul Nebulae

Prabhakaran (Prabhu), Buraq and Mleiha, UAE, 14, 15 and 21 September 2020

Prabhu says: "Processing the colours of narrowband images is a bit tricky, but I was so delighted to see the colours the way I wanted."

Equipment: ZWO ASI 1600MM Pro camera, Samyang 135mm f/2.8 lens, Sky-Watcher AZ-EQ6 mount **Exposure:** 4.5 hours: Ha 4x 10', 6x 5', 10x 3', OIII 3x 10', 7x 5', 4x 3', SII 3x 10', 11x 5', 1x 3' **Software:** PixInsight, StarNet++

▽ The Crescent Nebula

Jamie Macdougall, Ely, Cambridgeshire, 1-13 September 2020

Jamie says: "I captured the Crescent Nebula in 2015. After five years of building up my processing skills and saving up for new equipment, I thought I'd give it another go."

Equipment: ZWO ASI 1600MM Pro camera, Sky-Watcher Evostar 80ED DS-Pro refractor, Sky-Watcher NEQ6 Pro mount **Exposure:** Ha 54x 600", OIII 66x 600" **Software:** Siril, StarNet++, Photoshop

△ The Triangulum Galaxy

Emil Andronic, Bushey, August 2018 and September 2020

Emil says: "Capturing the Triangulum Galaxy has been a pleasure since I started shooting it in 2018. I got good results with my Canon 600D in 2018, but I decided to add more data to it this year with the ASI 294MC. I'm very pleased with the result."

Equipment: Canon 600D DSLR, ZWO ASI 294MC Pro camera, TS65 quadruplet f/6.5 imaging telescope, Sky-Watcher EQ3 mount **Exposure:** 43x 600", 43x 300", 159x 300" **Software:** APT, SGP, PixInsight, Photoshop

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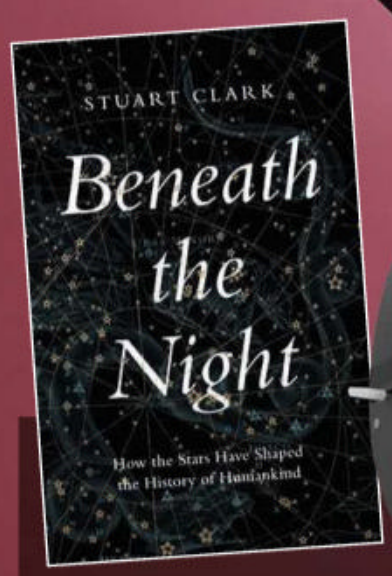

HOW WE RATE

Each product we review is rated for performance in five categories. Here's what the ratings mean:

★★★★★ Outstanding ★★★★★ Very good
★★★★★ Good ★★★★★ Average ★★★★★ Poor/avoid

Sky-Watcher StarQuest 130P Newtonian reflector

An easy-to-assemble 'grab and go' telescope that gives rewarding views

WORDS: PAUL MONEY

VITAL STATS

- **Price** £199
- **Optics** 130mm (5.1-inch) parabolic mirror
- **Focal length** 650mm (f/5) focal length
- **Mount** Equatorial/ altazimuth mount
- **Focuser** Rack and pinion
- **Extras** Red dot finder, 1.25-inch 10mm and 25mm eyepieces, slow-motion control cables
- **Weight** 8kg
- **Supplier** Optical Vision Ltd
- **Tel** 01359 244200
- **www.**optical vision.co.uk

During this strange year, one thing that has come to the fore is how astronomy has brightened people's lives, so it's good to see this stylish, new scope from Sky-Watcher, the StarQuest 130P.

Looking smart and fresh in its white, black and green livery, the StarQuest 130P's tube length is nice and short, so it's not unwieldy for newcomers to handle. The tube holds a 130mm primary mirror with a focal length of 650mm, which gives a focal ratio of f/5. The mount gives a fresh take on traditional EQ1 and EQ3 designs – it's more compact, using Capstan-style locking clutches and is a much smaller size, which helps to make it lightweight, yet robust. Slow motion controls are included for both axes, while the mount can also be adjusted to be an altazimuth style if needed.

The mount sits on an aluminium tripod with an accessory tray for the two supplied eyepieces: 25mm giving 26x magnification and 10mm giving 65x. A red dot finder, counterweight and bar completes the setup. The system only weighs 8kg and it's easy to assemble, which means the StarQuest 130P is much more likely to get used than a more awkward setup, and less likely to get left in corner of a room without any action.

We checked the collimation of the optics and found they were still aligned despite the transportation, so we went straight to work – late into the next clear night. Optically the system is classed as 'fast' at f/5, so we looked at Altair (Alpha (α) Aquilae) and noted how the star appeared from one side of the view to the other using the 25mm eyepiece. Altair appeared as a good tight pinprick for 70 per cent of the view, but then showed some distortion towards the field edges, which is on a par with many other scopes we have tested.

We then viewed the wonderful double star Albireo (Beta (β) Cygni) in Cygnus, first with the 25mm eyepiece and then with the 10mm. The colours were well defined with gold and sky blue, and the components were clearly separated with dark space between them. We also had a good view of Gamma (γ) Andromedae, which appeared as a tighter version of Albireo, and it was also a pleasing sight when we added our own 2x Barlow lens.

Taking a tour

Turning to the summer sky we took a tour from high up in the constellation of Cygnus, the Swan, starting with star cluster M39, which looked like a sprinkle of diamond dust with its clearly defined triangular nature. Other clusters we viewed included its smaller cousin, M29 and the Wild Duck Cluster, M11, showing a strong hint of the 'V formation' of stars that gives it its name. The Sagittarius Star Cloud looked mottled with the ▸

An easy to use mount

Equatorial mounts for ranges of smaller telescopes can often look a little clumsy, difficult to use and quite frankly old-fashioned, but the mount with the StarQuest 130P is an interesting, more compact and modern design. This makes it easier to set up and use, especially as it comes as one unit ready assembled. Just pop it onto the tripod, bolt it in place and then put the scope onto the Vixen-style head, and you are ready to go.

It uses Capstan-style locking knobs on both axes, which replace the more traditional side knobs; and we found that after a little practice it became second nature to loosen these to make large-scale adjustments to the direction the scope is pointing. The mount also has two slow-motion controls for fine tuning in both RA (right ascension) and dec. (declination) settings, which were smooth and easy to use. It can also be configured in an altazimuth position, which is useful for viewing awkward to reach areas of the sky such as near the celestial pole, or for viewing landscapes during the day.

Tube rings

The tube rings safely hold the telescope in place via locking bolts that can be slightly loosened to allow the tube to be rotated for a more comfortable viewing position. They attach to the mount via a standard Vixen-style bar which is a fetching metallic green.

Eyepieces

Two basic eyepieces with rubber eyecups are supplied, a 25mm giving 26x magnification and a 10mm for a higher 65x magnification. They work well for this focal system and give pleasing views of a wide range of celestial targets, from lunar to planetary and brighter deep-sky favourites.

Tripod

The aluminium tripod is a good match for the StarQuest 130P, as it is lightweight yet strong enough to support the telescope. It has adjustable legs to make the viewing height more comfortable and a useful accessories tray, which helps to spread the tripod's legs and lock them in position.

Focuser and finder

The focuser is a standard rack and pinion style that takes 1.25-inch fit eyepieces. We noticed there was a little play when focusing, but nothing serious. The finder is a standard red dot type with adjustable brightness, so as not to overpower the view at its lowest setting.

FIRST LIGHT

◄ The Moon captured with an iPhone XR and smartphone adaptor attached to the StarQuest 130P. It was taken using the 25mm eyepiece, with an exposure of 1/292" at ISO 25, and zoomed in and slightly cropped

KIT TO ADD

1. Sky-Watcher StarQuest RA motor drive

2. Sky-Watcher 1.25" 2x deluxe Barlow lens

3. Sky-Watcher dual LED torch

► 10mm eyepiece; and later in the night we were rewarded with a sparkling view of the Pleiades, M45, low in the east and framed nicely in the 25mm eyepiece.

Turning to nebulae we began with a favourite, the Omega Nebula, M17, while its neighbour, M16 was more impressive as it revealed the cluster with a hint of haziness surrounding it. Higher up, the Dumbbell Nebula, M27, was well defined and the 10mm gave a good view too. Over in the constellation of Lyra, the Harp, we had a good view of the Ring Nebula, M57, in the 10mm eyepiece – with a nice 'hollow' to its ring on display. Switching to the 25mm we viewed galaxy pair M81 and M82, with both fitting in the eyepiece view, the former was revealed as a hazy oval and the latter as a sliver of light.

The almost full Moon fitted in the field of view of the 10mm, revealing lots of detail – it was rewarding to watch the changing phase with this scope and see how it highlights the craters and seas. Although it' s not an imaging scope, we successfully attached a smartphone adaptor to the 25mm eyepiece and zoomed in to capture a lunar image with our iPhone XR (see above).

Overall, the StarQuest 130P is a well-made and easy-to-use telescope that will give a lot of pleasure to first-time stargazers; it could also work as a simple grab-and-go option for more advanced observers.

Optics

The 130mm (5.1-inch) parabolic mirror has a relatively short, or 'fast', focal length of just 650mm, giving the system a focal ratio of f/5. Along with the secondary mirror, it is housed in a white aluminium tube, which makes it lightweight and easy to handle.

VERDICT

Assembly	★★★★½
Build & Design	★★★★½
Ease of use	★★★★½
Features	★★★★½
Optics	★★★★½
OVERALL	★★★★½

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FROM THE MAKERS OF BBC Sky at Night MAGAZINE

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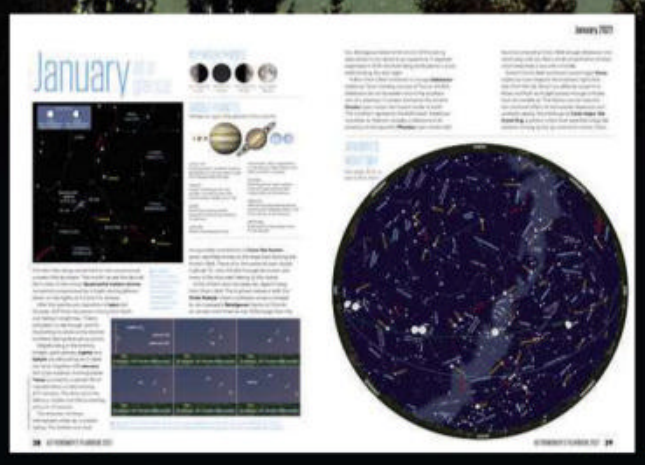

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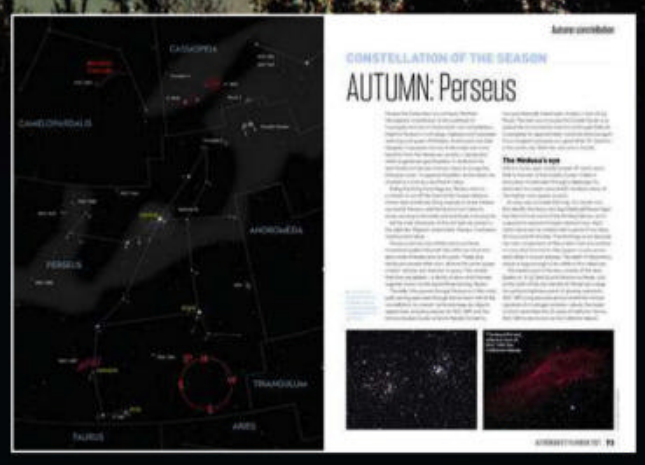

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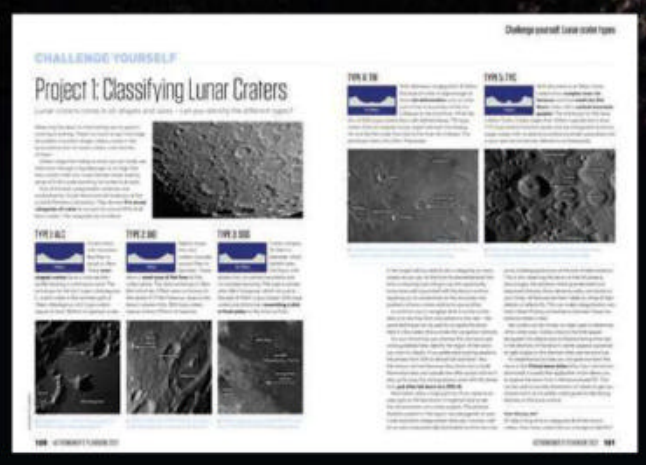

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FIRST LIGHT

National Geographic 114/500 Compact Telescope

A starter scope that offers memorable views for budding astronomers

WORDS: CHARLOTTE DANIELS

VITAL STATS

- **Price** £115
- **Optics** 114mm (4.5-inch) primary mirror
- **Focal length** 500mm, f/4.4
- **Mount** Tabletop Dobsonian
- **Eyepieces** 20mm and 6mm eyepieces supplied, 1.25-inch fit
- **Accessories** 2x Barlow lens, Moon filter, LED red dot finder, compass, planisphere, Stellarium CD
- **Weight** 4.3kg
- **Supplier** Telescope House
- **Tel** 01342 837098
- **www.**telescopehouse.com

The National Geographic 114/500 Compact Telescope is a tabletop Dobsonian that offers three times more light-gathering capability than the company's smaller 76mm model. This increase in light grasp enables you to view many popular deep-sky objects as well as planets and lunar features.

From the moment we opened the box, we noted that only minimal effort was needed to get up and running as the tube and mount were already assembled. The accompanying accessories consist of two eyepieces (20mm and 6mm), a 2x Barlow lens for planetary viewing, a lunar filter, a planisphere and a CD with Stellarium software. The telescope's 'straight out of the box' feel is exactly what is needed for building the confidence and maintaining the interest of young astronomers: it can be picked up at a whim on a clear night and packed away in minutes.

The brightness of the LED finder can be adjusted, which makes it easier to locate fainter deep-sky objects. Moreover, this finder slips into the bracket on the tube without requiring screws to fix it in place. We were also pleased with the integrated compass and equipment tray on the rotating base; this helped us to direct the scope towards north accurately, while the two eyepiece holder cups held our eyepieces snugly while we transported the scope outside. The wooden base felt robust, and once it was positioned on our patio table it was secured firmly by its rubber feet.

Starting out

The 114/500 is ideal for targets that those new to the hobby will want to enjoy, including star clusters, nebulae and planets. During our late September observing sessions we viewed the Moon, deep-sky objects including the Double Cluster and the Pleiades, M45, along with several planets. You'll also find, as winter approaches, the scope is well suited for viewing seasonal objects, such as the Orion Nebula and Andromeda Galaxy. The instructions provided are thorough, and even provide a small 'target list' to get users started. Even better, there's a page showing ►

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Size matters

The 114/500's 114cm (4.5-inch) primary mirror is a step up in size from a number of tabletop Dobsonians, yet still light and portable. The relatively large aperture enhances the scope's light sensitivity and makes it suitable for a broad range of objects; the larger the diameter of a telescope's mirror, the better its light grasp and ability to resolve detail, which improves the viewing experience.

The compact size of the scope is also a bonus. Although the 114/500 is one and a half times the size of its smaller sibling, the 76/350, it's only just over 1kg heavier. It will also fit easily into the boot of a car, allowing you to transport it to dark-sky locations to be put through its paces.

Ultimately, the relatively short focal length and light-gathering capability of this tabletop Dobsonian will help to enthuse beginner astronomers, as viewing won't be limited to the Moon. You will find that planets and brighter, more well-known deep-sky objects also make rewarding targets.

LED finder

Beginners will most likely find a red dot finder is more intuitive than a traditional finderscope. Designed to help users to point the scope in the right direction, the red dot finder complements the 114/500's wide field of view and it's easy to accurately align the finder's field of view with the telescope's.

Built-in equipment tray

The rotatable wooden base comes with two eyepiece cups, so you can manoeuvre this scope in the dark without dropping your kit. It is a simple, but effective addition to the setup and one we haven't seen on many tabletop Dobsonians; it also makes the 114/500 space efficient, reducing clutter.

Altazimuth scales

Situated on the side and base of the 114/500, the altitude and azimuth axes's 'setting circle' scales allow users to manually find objects using coordinates from planetarium programs or star charts. Combined with the planisphere and Stellarium software access, the 114/500 educates users in a variety of ways to navigating the night sky.

Eyepieces and 2x Barlow lens

The 114/500 comes with 20mm and 6mm eyepieces; combined with the Dobsonian's 500mm focal length, these provide magnifications of 25x and 83x respectively. The 2x Barlow lens is essential equipment for observing the planets and doubles the magnification of the eyepieces when it's used with them.

FIRST LIGHT

Useful accessories

The 114/500 comes with a lunar filter, planisphere and a CD with Stellarium planetarium software. These go well with the accessories provided: using the compass it is easy to navigate with the planisphere, while Stellarium provides the coordinates needed to use the altazimuth 'setting circle' scales, and the filter enhances lunar viewing.

KIT TO ADD

1. Bresser 25mm Plössl eyepiece

2. Bresser 10mm Plössl eyepiece

3. Explore scientific Sun Catcher solar filter for 110-130mm telescopes

▸ the field of view for these objects as seen through both eyepieces provided, which helps us know what to expect from the kit.

Using the wide 20mm eyepiece, we located objects easily, before swapping to the narrower 6mm for a closer look. When we switched from viewing Vega (Alpha (α) Lyrae) with the 20mm to the 6mm eyepiece, we couldn't initially achieve pin-sharp focus, but this was mostly rectified through collimation – aligning the primary and secondary mirrors using a collimation cap or Cheshire eyepiece. We did notice some distortion remained when viewing through the 6mm, but this was most likely due to a mixture of seeing conditions and overall eyepiece quality. However, the distortion was only slight and not enough to prevent us from enjoying good views of the night sky, including bright star clusters.

We popped the 2x Barlow lens on and swung the scope to view several planets including Mars, Jupiter and Saturn. We were able to view the targets we would want to show beginners as part of a first planetary viewing experience, including three of Jupiter's Galilean moons and its North and South Equatorial Belts, which was further confirmation of this telescope's ability to perform well.

A rotating tabletop mount needs to be easy to move yet firm when it's settled on an object – so that the field of view isn't adjusted by nudges or by someone holding the eyepiece mid-view – but we noted that the 114/500's rotation was a little too stiff, meaning it was difficult for us to make minor adjustments. When attempting to make incremental movements we also found some flex in the setup, making fine-tuning a little tricky.

However, when we viewed an almost full Moon, putting the lunar filter on to reduce brightness and allow comfortable viewing, the 114/500 met our expectations again, revealing engaging details in its craters and seas. Given the ease to setup, this scope is perfect for users to make impromptu lunar tours, regardless of their age or capability.

To sum up, the 114/500 is a good starter scope, designed to capture, educate and encourage those who are new to astronomy. It will offer memorable first time views of the Moon and other objects, without being complex and off-putting to use.

VERDICT

Assembly	★★★★☆
Build & design	★★★★☆
Ease of use	★★★★☆
Features	★★★★☆
Optics	★★★☆☆
OVERALL	★★★★☆

ALL PICTURES: @THESHED/PHOTOSTUDIO

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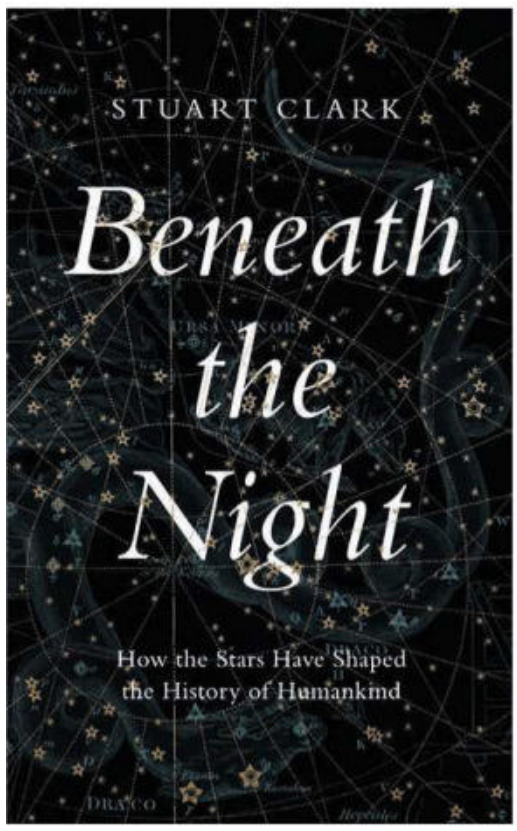


Beneath the Night

Stuart Clark
Guardian Faber
£14.99 ● HB

What is it about the sky at night that has captivated human beings for centuries? This is the central question driving Stuart Clark's excellent book.

While there are many popular science books charting the history of great astronomical discoveries, surprisingly little has been written about the human relationship with the night sky. This book explores that connection, how the history of humankind is also the history of our changing relationship with the cosmos.

The story starts with the most ancient, prehistoric civilisations and how they studied and worshipped the night sky. Using the latest archaeological evidence and theories, Clark shows how for those early civilisations, the stars were the home of the gods, beginning a long association between the night sky and religion. As he proceeds through the centuries, he explores the connections made between the night sky and agriculture, human behaviour (in the form of astrology) and music (the music of the spheres).

Interestingly, Clark makes a case for the scientific revolution almost severing humanity's relationship with the night sky, turning it from the sublime into the functional. Luckily, it did not destroy that relationship entirely, but merely shifted it. Artists, poets and writers still found the sublime in the heavens. Philosophers and astronomers too simply had to look further out, reflecting with wonder on the Universe beyond our Solar System and the mysteries contained there. The 20th century transformed our relationship with the heavens again, sending humans into space, from where they could see our planet and the whole human race anew.

This book makes you rethink the traditional story of the history of astronomy. It reminds you to look up, not to seek out a particular object but to simply bask in the vastness of our Universe. It tells a rather male, Eurocentric story of the history of astronomy, but since this is there as a familiar backdrop rather than the central theme, it makes sense.

▲ **Were our cave-dwelling ancestors the first astronomers?**

GORODENKOFF/ISTOCK/GETTY IMAGES

Clark's experience as a science writer shows, making this an effortlessly readable book. It is definitely one to pick up if you ever wondered why astronomy is so important. ★★★★★

***Emily Winterburn** is the author of* The Stargazer's Guide: How to Read our Night Sky

Interview with the author
Stuart Clark

Who were the first astronomers?

Trace back in time and you run out of written records. We have no idea when the constellations were defined. Taurus, for example, seems to be a super-early constellation and appears, we think, on some of the cave paintings in Lascaux, France. There is a picture of half a bull, and just above the shoulder looks like a representation of the Pleiades. This was painted about 19,000 years ago, so it seems that someone looked up in the night sky and pictured a bull in that location, the same as we do today.

How did early humans use astronomy?

It appears astronomy was used to set the time of winter ceremonials. There were times of the year when different hunter-gatherer communities would come together to trade, marry or agree loans of livestock or food. The times of these were set by astronomical means, and each of the tribes seems to have had astronomers to determine when to go to the winter ceremonial.

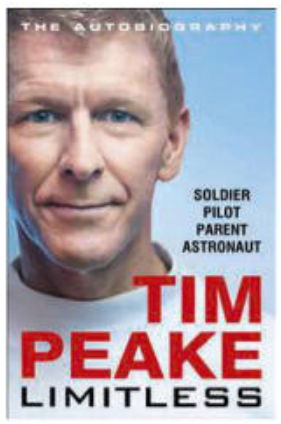
Who played the biggest role in developing astronomy?

In terms of using the night sky for timekeeping and navigation, it was Johannes Kepler. He was interested in the arrangement of the planets – these five wandering 'stars', Mercury, Venus, Mars, Jupiter and Saturn, all the naked-eye planets, didn't fit with any timekeeping. Kepler found three mathematical laws defining planetary motion, which shows the night sky is mechanical, like clockwork. If we can understand something like celestial motion with mathematics, we can understand anything.

***Stuart Clark** is an award-winning astronomy journalist and broadcaster, and fellow of the Royal Astronomical Society*

Limitless

Tim Peake
Century
£20 ● HB



Astronaut biographies aren't always quite the thrilling tale you hope for: after all, their job is to faithfully follow a long rule book with military precision. Tim Peake's autobiography is a rare example of one that lives up to expectations, packed with bizarre, thrilling, stomach-churning anecdotes about his life.

Peake takes us from his early experiences with homemade explosives through his days as a flair bartender, to the army and test pilot training, right up to touching down from space and being whisked away on a world tour. In between, he gives tips on how to crash-land in a helicopter, how to behave under interrogation, and how to best confront Jeremy Paxman. I often found myself holding my breath – some tales are definitely not for the squeamish, and it will certainly dissuade readers of any notion that astronauts lead a glamorous life.

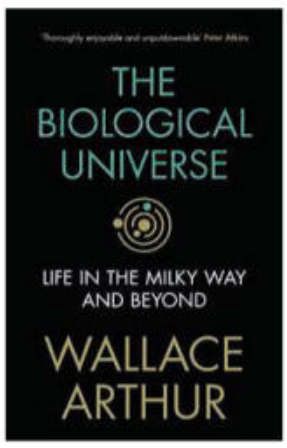
In places the anecdotes feel a bit stretched out; this 500-page book could be half its length. Peake also writes of the army with glowing praise, sometimes to the point where it reads like recruitment material rather than a balanced account. When he comes to his brief time on the ISS, it is somewhat underwhelming. One almost feels cheated that everything went so straightforwardly, with no terrible calamity, nor any need for the survival skills he honed in Sardinian caves.

But while the section on the Space Station may not be what we might expect, the book gives an incredible insight into the mind of an adrenaline junkie, test pilot, father and astronaut which many more than just spaceflight enthusiasts will enjoy. ★★★★☆

***Katie Sawers** is a student of physics and astronomy at the University of Glasgow*

The Biological Universe

Wallace Arthur
Cambridge University Press
£20 ● HB



Are we alone in the Universe, or are there other lifeforms 'out there'? This is one of the most scientifically and philosophically profound questions that humanity can ask. And as evolutionary biologist Wallace Arthur argues in this book, we may be tantalisingly close to finally achieving an answer.

Arthur surveys the landscape of recent advances in biochemistry, microbiology, planetary science and astrophysics, and concludes that microbial life must be common across the Galaxy, and that perhaps there are even other intelligent species too. We are right on the brink, he argues, of another Copernican Revolution – this time delivering the staggering realisation that we are not at the centre of the biological universe either.

Astrobiology is deeply interdisciplinary, encompassing research from across many fields of science, and it's also very fast-paced, with headline-grabbing discoveries being made at an ever-faster rate. This means it can be very tricky to write an up-to-date account for the general public. Arthur has done an admirable job pulling together all these different fields and his explanations of tricky topics are clear.

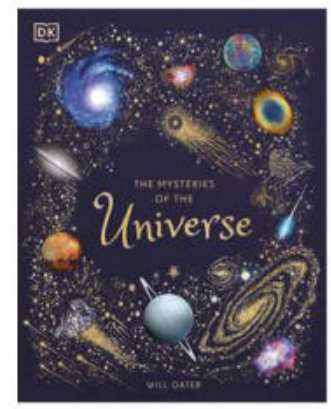
For me, however, *The Biological Universe* just feels a bit flat and disjointed. The language can be staid and the narrative jumps around between disparate topics without a sense of flow from one section to the next, or the smooth development of ideas and themes. This is a reasonable summary of the current state-of-play, but it lacks verve and a real sense of excitement. ★★★☆☆

***Lewis Dartnell** is the author of* Origins: How the Earth Shaped Human History

The Mysteries of the Universe

GREAT FOR THE KIDS

Will Gater
DK Children
£20 ● HB



Do judge a book by its cover; this one is as gorgeous as it looks. Not only that, it contains the full glory of the cosmos in a language that's simple and engaging enough for an eight year-old.

Although *The Mysteries of the Universe* is aimed at children, it really is a treat for all ages. Visually stunning, with a fabulous selection of space photos, artworks and illustrations, it is also all-encompassing in its astronomy.

We start our adventure gazing at the sky on Earth, and from here the book sweeps seamlessly outwards: to the Moon, the inner and outer planets, right to the Oort Cloud, with everything in between. From there the Universe unfolds: we see nebulae, black holes and star-forming nurseries. We leave the Milky Way and whizz past the Large and Small Magellanic Clouds, Stephan's Quintet; past spiral, elliptical and lenticular galaxies and far back to the distant early Universe.

While easy to dip into, this book does not skimp on science or detail; difficult ideas are delivered in a form that young readers will understand. Neutron stars are the "zombies of interstellar space", so dense that a "sandgrain-sized fleck" will weigh as much as 1,500 jumbo jets. Kids are introduced to our Local Group of galaxies, the Hubble Deep Field and the cosmic microwave background – concepts that adults may find mind-bending.

Its delightful presentation – gold trim and golden comet tails, full-page NASA photos – are catnip to curious kids. I can't remember my own two bickering over the post-review ownership of a book before.

While life on Earth may be challenging, this book goes a long way to inspiring the next generation and showing them just how big and wonderful the world of astronomy can be. ★★★★★

***Shaoni Bhattacharya** is a science writer and journalist*

Ezzy Pearson rounds up the latest astronomical accessories

GEAR

1 Helios 2x40 Star Field Binoculars

Price £89 • **Supplier** Tring Astronomy Centre
Tel 01442 822997 • **www.tringastro.co.uk**

With a wide field of view and low magnification, these binoculars give you the same viewing experience as using the naked eye but with super-enhanced vision. Ideal for taking a deeper look at wide-field objects, such as constellations of the Milky Way.

2 Pegasus FlatMaster 150 flat field illuminator

Price £169 • **Supplier** William Optics
Tel 01353 776199 • **www.widescreen-centre.co.uk**

ADVANCED Flat field panels provide a uniform illumination source to ensure you have the highest quality flat field frames for processing your images. This model has an adjustable brightness, allowing you to fine tune to best suit your setup.

3 Milky way mug

Price £8.99 • **Supplier** Society for Popular Astronomy • **www.popastro.com**

Whether it's tea or coffee carrying you through a night's observing, one side of this mug lets your fellow observers know "I make my drinks the milky way", while the other shows off a beautiful image of the starry night sky.

4 Cosmos socks

Price £4.99 • **Supplier** Dedoles • **www.dedoles.co.uk**

Keep one foot on the ground and one in the night sky with these astronomy-themed socks. One sock features a host of planets and stars, while the other has a pair of telescopes ready to observe them all.

5 Artisan Solar System chocolates

Price £15 • **Supplier** Caithness Chocolate
www.caithnesschocolate.co.uk

Give the chocoholic astronomer in your life the gift of the Solar System. The Sun and eight planets are all beautifully rendered in milk chocolate with a delicious salted caramel filling and accompanied by a belt of three cinder toffee asteroids.

6 Sky-Watcher 90° polar scope eyepiece

Price £79 • **Supplier** Harrison Telescope
Tel 01322 403407 • **www.harrisontelescopes.co.uk**

It can be a pain in the neck trying to look through your polar scope when your mount is set up at an awkward angle, but this 90° eyepiece lets you take in the view from whichever angle suits you.

Shaoni Bhattacharya interviews Andrew McDonald

Q&A WITH A SPACE EDUCATOR

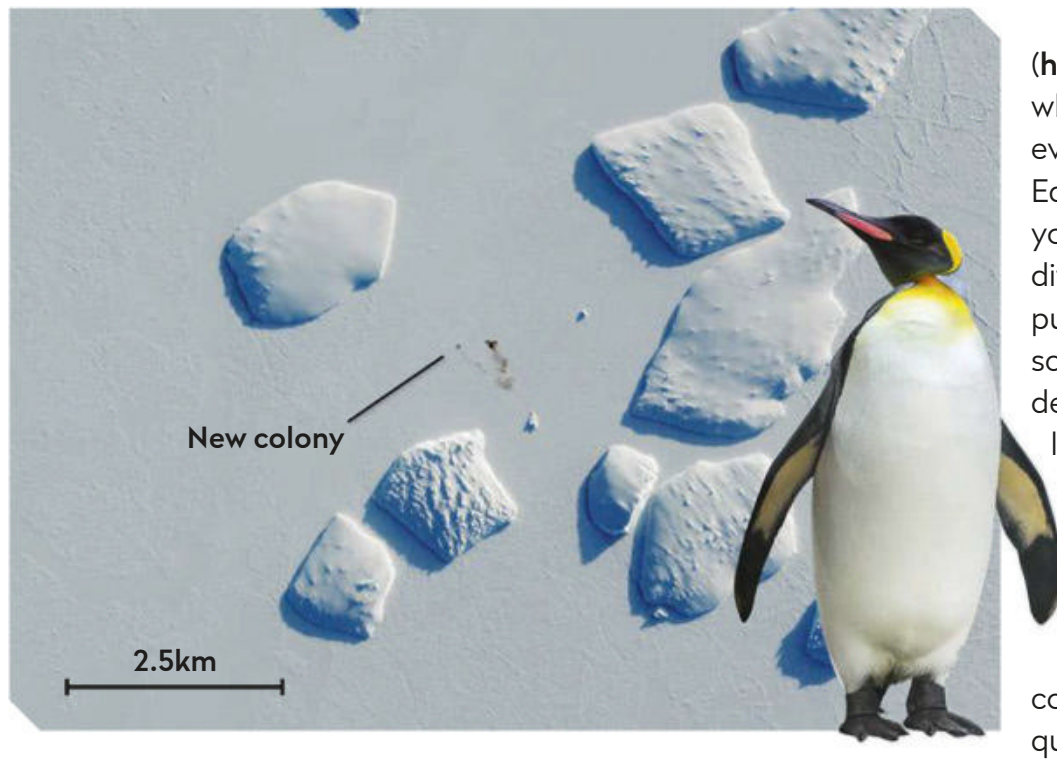
How a school science club inspired the British Antarctic Survey to harness ESA's Copernicus Sentinel-2 satellite to find new colonies of Emperor penguins

How did you and your pupils at Stirling High School become involved in a satellite study of penguins?
I was watching a David Attenborough programme where he was in Antarctica looking at various penguin colonies and he explained that they had been monitored using aerial photography. It got me thinking about whether it would be possible to monitor them from space, given the higher resolution of some of the new satellites. I came back to my small group of researchers, aged roughly 11 to 15, and we batted the idea around.

We looked at satellite data from the European Space Agency's Copernicus Sentinel-2, which gives us about a 20m square pixel on the ground; it's not super high resolution, but it's a lot better than previous satellites. Sentinel-2 also gives a range of wavebands, from the visible to short-wave infrared (SWIR). To help us find the colonies we looked for the guano (accumulated excrement). Having located the known colonies, we then looked at variations in the different wavebands to come up with a way of processing the imagery to best highlight penguin poo.

What does penguin poo look like from space?
The guano is a dark splodge against the icy background – effectively a dark brown stain. It changes through the breeding season: you can use it to track the movement of the penguins from one area to another. We found that we could improve on that even more by looking at the SWIR data, which gives a better resolution and therefore a better idea of the colony's boundary and where it actually is.

How did your pupils use the Sentinel-2 data?
The pupils came together as the Researchers in Schools Club (RISC), run in conjunction with the charity Institute for Research in Schools (IRIS). The idea is that it doesn't matter how young you are, you can still do real scientific research. It is an extracurricular club – my pupils did everything at lunchtime or in their own time.



▲ Pick up a penguin: British Antarctic Survey scientists used high-resolution images from ESA's Copernicus Sentinel-2 satellite to monitor the presence of penguin colonies

Dr Andrew McDonald is a physics teacher at Stirling High School and is a former Earth observation scientist with the British Geological Survey. He is also a lead educator for the UK's National Space Academy

We used the Sentinel Hub (**https://sentinel-hub.com**), which is free and open to everybody. As well as an Earth Observation browser, you can access data from different satellites. Some pupils worked out the coding script to do our guano detection, while others looked at multi-temporal images (images over time) that might be for different years, or within a single breeding season.

We did this for known colonies, but it raised the question of whether this technique could be applied to look for other colonies; that's what the British Antarctic Survey did.

How did your school club's work inspire British Antarctic Survey (BAS) scientists?
Within our research, BAS scientist Dr Peter Fretwell's name came up, so we emailed him. He kindly provided us with additional information about known penguin colonies and some of the work they had done. On the basis of that we could then go ahead with our research and we bounced results back to him.

When his paper with Dr Philip Trahan came out with the acknowledgement that we'd inspired him to do more – that was such a great boost for the RISC team. It was an absolute surprise; I downloaded the paper and I was thrilled on behalf of the pupils.

What did the BAS study show?
They identified a number of known colonies, but they also confirmed 11 new colonies [meaning there are 20 per cent more colonies than previously known]; that's a big deal because penguins are a good indicator species for climate change.

How can educators inspire young people in space or astronomy?
The best thing we can do is be enthusiastic, as the curriculum can be a little bit dry. It's about taking it away from just saying, "Okay we are doing rotational motion"; we can do that just as theory, or we can say, "Let's have a look at what that means for satellites in orbit" – and broaden it out to give context.

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THE SOUTHERN HEMISPHERE

With Glenn Dawes

Look out for the close encounter of Jupiter and Saturn – known as the 'Great Conjunction'

When to use this chart

1 Nov at 00:00 AEDT (13:00 UT)
15 Nov at 23:00 AEDT (12:00 UT)
30 Nov at 22:00 AEDT (11:00 UT)

The chart accurately matches the sky on the dates and times shown for Sydney, Australia. The sky is different at other times as the stars crossing it set four minutes earlier each night.

DECEMBER HIGHLIGHTS

December brings a 'Great Conjunction' between Jupiter and Saturn. You may have noticed them drawing closer, but on the 21st Jupiter overtakes Saturn and is just 0.1° distant. If you wish to view both in the same eyepiece, they are within 0.5° between the 17th and 26th. Although low in the twilight sky, around 40 minutes after sunset the planets should still have an altitude of about 15° from mid-Australian latitudes. On the 17th a thin crescent Moon can be seen 3° above the pair.

STARS AND CONSTELLATIONS

When looking at a star you might wonder if it's bright only because it is close to us. That is true for some, but certainly not the brightest luminaries in Orion. Rigel (beta (β)), Bellatrix (gamma (γ)) and Alnilam (epsilon (ε) Orionis), the centre Belt star are all blue/white supergiants with masses and temperatures and luminosities that dwarf our Sun. Betelgeuse (alpha (α) Orionis) is a red supergiant that is half as hot as the Sun, but if it replaced our star its surface would extend past the orbit of Mars.

THE PLANETS

Jupiter and Saturn will be low in the western twilight sky by the month's end and soon lost in the Sun's glow. Neptune is now in the northwest evening sky, departing around midnight. Mars and Uranus follow Neptune across the sky, setting in the early morning. They are best observed in the evening. Venus remains the Morning Star and is dropping towards the Sun. On the morning of the 13th, Venus has a close meeting with the crescent Moon in the eastern dawn sky.

DEEP-SKY OBJECTS

The Pleiades open star cluster, M45, in Taurus (RA 3h 47.0m, dec. +24° 07') contains many double stars, some well suited for binoculars such as Atlas (27 Tauri) and Pleione (28 Tauri) at mag. +3.6 and mag. +5.1 and 5 arcminutes apart, and 21 and 22 Tauri, at mag. +5.8 and mag. +6.4 separated by 3 arcminutes.

RW Tauri (RA 4h 03.9m, dec. +28° 07') is an impressive variable star of the eclipsing binary type. Earth happens to be in the plane of this binary pair's orbit, so we see a regular dimming as the fainter star passes in front of its brighter companion. RW Tauri spends most of the time at 8th magnitude. Every 2.769 days it dims to 12th magnitude and then recovers, taking eight hours – a close orbit. Charts with comparison star magnitudes can be downloaded from the American Association of Variable Stars (AAVSO).

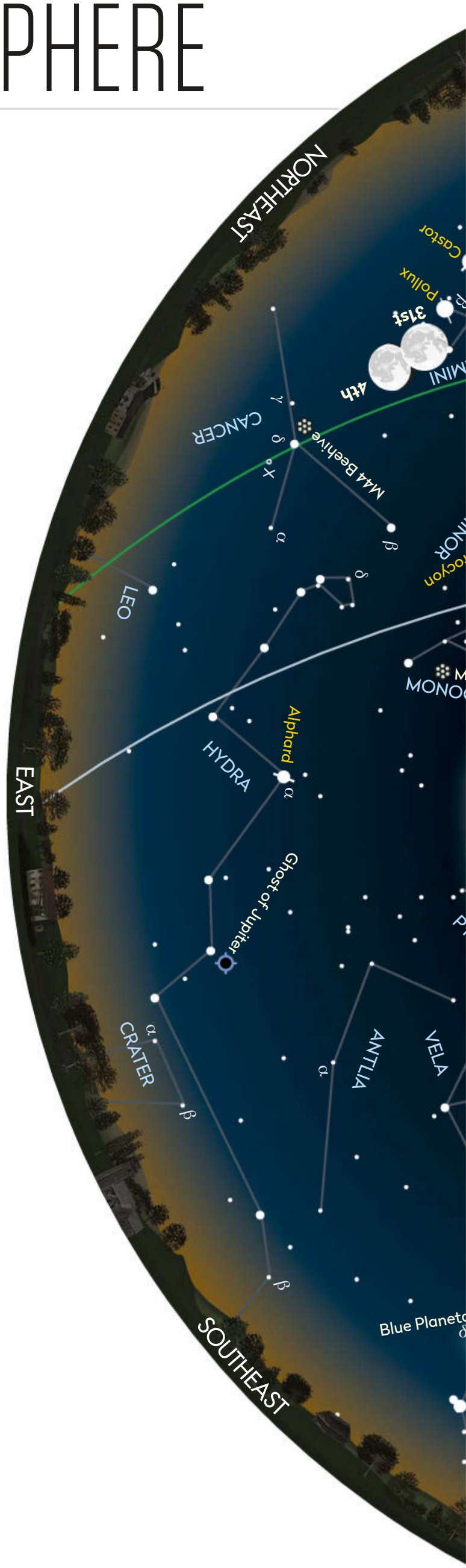
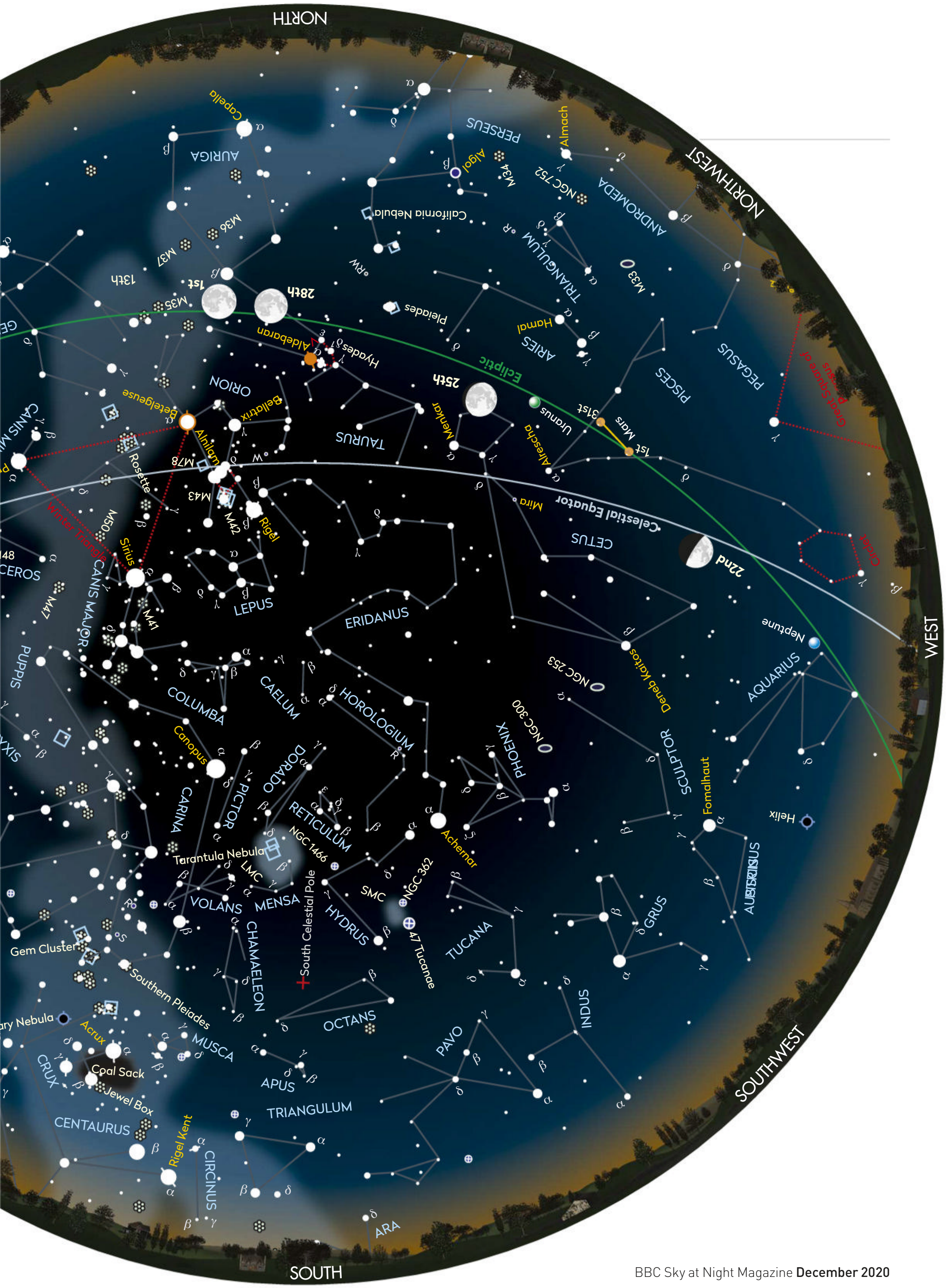


Chart key

- GALAXY
- OPEN CLUSTER
- GLOBULAR CLUSTER
- PLANETARY NEBULA
- DIFFUSE NEBULOSITY
- DOUBLE STAR
- VARIABLE STAR
- COMET TRACK
- ASTEROID TRACK
- METEOR RADIANT
- QUASAR
- PLANET

STAR BRIGHTNESS:
- MAG. 0 & BRIGHTER
- MAG. +1
- MAG. +2
- MAG. +3
- MAG. +4 & FAINTER

CHART: PETE LAWRENCE


NORTH
NORTHWEST
WEST
SOUTHWEST
SOUTH
Capella
AURIGA
PERSEUS
Algol
M34
Almach
NGC 752
ANDROMEDA
California Nebula
TRIANGULUM
M33
M36
M37
13th
1st
28th
M35
Pleiades
Hamal
ARIES
PISCES
PEGASUS
Great Square of Pegasus
Circlet
Aldebaran
Hyades
Ecliptic
25th
Menkar
Alrescha
Uranus
31st
1st Mars
ORION
Betelgeuse
Bellatrix
Alnilam
M78
Rosette
M43
M42
Rigel
Sirius
Winter Triangle
CANIS MAJOR
M47
M41
LEPUS
TAURUS
Mira
Celestial Equator
CETUS
22nd
ERIDANUS
Deneb Kaitos
NGC 253
Neptune
AQUARIUS
PUPPIS
COLUMBA
CAELUM
HOROLOGIUM
NGC 300
PHOENIX
SCULPTOR
Fomalhaut
Helix
Canopus
CARINA
PICTOR
DORADO
RETICULUM
NGC 1466
Tarantula Nebula
LMC
Achernar
SMC
NGC 362
VOLANS
MENSA
HYDRUS
47 Tucanae
TUCANA
GRUS
AUSTRINUS
Gem Cluster
CHAMAELEON
South Celestial Pole
Southern Pleiades
OCTANS
INDUS
PAVO
Acrux
MUSCA
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TRIANGULUM
CENTAURUS
Rigel Kent
CIRCINUS
ARA